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Peter Štarchoň
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Hybrid Management Organisations and Processes Using the Example of a Non-profit Organisation

Jürgen Weltermann, Lothar Huschbeck, and Peter Markovič

Abstract This article analyses the management practices of hybrid organisations, using the Order of St. John as a case study. It explores transitioning from the traditional VUCA (Volatility, Uncertainty, Complexity, Ambiguity) to the more recent BANI (Brittle, Anxious, Nonlinear, Incomprehensible) framework, emphasising human reactions to unpredictable events. The study investigates the principle of obedience within the Order of St. John, a non-profit organisation dating back to the eleventh century, and analyses its relevance in modern management. The research highlights the Order's hierarchical structure, which combines traditional obedience with modern management methods such as agile and hybrid management. The findings suggest that integrating traditional principles with contemporary approaches can enhance organisational efficiency and adaptability in complex environments. This study contributes to understanding how historical management practices can be adapted to address current and future challenges in non-profit and for-profit sectors.

Keywords Obedience principle · Management methods · Hybrid management

1 Introduction

Corporate management is characterised by rapid and unpredictable changes in supply chains, markets and networked technologies (volatility), which not only make future developments challenging to predict (uncertainty) but also do not allow for clear

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answers due to their multi-layered nature (complexity) and multiple meanings (ambiguity). The resulting acronym VUCA was formed at the United States Army War College at the end of the twentieth century to reflect the problematic corporate management conditions better. Barber [1] at the beginning of the twenty-first century, the VUCA term spread to all areas of companies and organisations, especially since digital transformation required a holistic understanding of strategic corporate management. A newer model is increasingly replacing the VUCA model to describe the current corporate management challenges better. This model goes further and describes a (b)rittle, (a)nxious, (n)onlinear and (i)ncomprehensible (BANI) environment. Cascio [2]. The main difference is that VUCA focuses on describing the environment. In contrast, BANI focuses more on human reactions and feelings to chaotic and completely unpredictable events such as pandemics or climate change, which can also significantly impact businesses. BANI also offers more specific coping strategies, such as the RAAT approach (Resilience, Mindfulness, Adaptation, Transparency). For companies and executives, the transition from VUCA to BANI will bring the following benefits:

- Development of strategies for the early detection and management of unforeseeable crises
- Promoting resilience and flexibility in organisational structures
- Creating a culture of mindfulness for better stress management and emotional regulation
- Focus on short-term, adaptable goals instead of long-term, rigid plans
- Investing in risk management tools and detailed contingency plans

In this context, it is intended to investigate an even older and lesser-known (obedience) model to see if it can provide a better framework for understanding and addressing the challenges in an increasingly complex and unpredictable world. To this end, the Order of St. John, founded in the eleventh century, which emerged from the "Balley Brandenburg of the Knightly Order of St. John of the Hospital of Jerusalem" [3], will be examined in more detail. The starting point was a hospital in Jerusalem founded in 1099, dedicated to John the Baptist, where sick and injured pilgrims were cared for. Henckel and Graf [4] the events took place when European powers were increasingly interested in sites in the Middle East. Under Gerhard Sasso's leadership and through the Crusades' influence, the Order developed from a community of pious lay brothers that offered charitable support to pilgrims and the sick to an organisation that also took on military tasks. The Knights of the Order guided pilgrims on their way, defended them against predatory attacks, and participated in numerous battles. After the conquest of Rhodes in 1309, [5] the Order of St. John created an important navy of the Order. Taaffe [6] this fought piracy in the Mediterranean and protected "Christian seafaring". The order split up during the Reformation and the political changes in Europe in the sixteenth century. Merzbacher [7] the Protestant branch, known as the Knights of St. John [3], established itself primarily in northern and central Germany and the Baltic regions. This development was characterised by the acceptance of the Protestant doctrine by parts of the Order of St. John, who thus formed their own identity within the original Order of St. John.

Wedekind [8] in 1802, the Order returned to Germany after the defeat of Napoleon. Wedekind [8] in 1812, the Prussian King Frederick William III named the Order of St. John the Protestant Order of St. John and gave it the task of caring for the poor and sick in Prussia. Wedekind [8] in the twentieth century, the Order developed into a modern welfare organisation, which is still involved in rescue services (rescue stations and disaster control operations), social work (hospitals, care for the elderly, childcare) and foreign aid (help in crisis areas). The Order of St. John focuses on medical care and help for the needy. Unlike the Order of Malta, which continued its activities as a sovereign order of chivalry and established its own territorial rule in Malta, the Order of St. John focuses on continuing its humanitarian missions, adapted to current needs and challenges. The Order of St. John thus rose to become one of the largest aid organisations. Nevertheless, the Order of St. John preserves its traditions and values. The members are still committed to charity, helpfulness and commitment to the Christian faith. The Order of St. John promotes interreligious dialogue and cooperation between religions. The Order is involved in numerous projects that unite people of different faiths and promote mutual understanding. In this context, the Order of St. John is a non-profit organisation where tasks and objectives can only be accomplished in the long term because entrepreneurial structures are necessarily used and further developed. Incidentally, large non-profit organisations differ from for-profit corporations in that non-profit corporations are self-owned and committed to the common good. In contrast, for-profit corporations primarily intend to maximise their profits. Nevertheless, similarities also concern particular aspects of sustainability, such as the attitude of their founders or their successors and the respectful treatment of their employees. For the sake of completeness, it should be mentioned that not only non-profit organisations have survived for centuries, but also profit-oriented companies such as the Japanese company HOSHI ONSEN, which has existed since 718. The company designated as an example must also face exogenous risk factors, particularly wars and economic crises. In this respect, it is a learning (breathing) company that [9] must be managed strategically and requires the correct analytical assessment of its strengths and weaknesses. The "3C approaches" (Customers, competitors, company), which apply to all organisations and companies, are suitable for this purpose. Ohmae [10] since non-profit organisations neglect the idea of profit maximisation, the volunteer sector needs highly motivated and ethically stable managers with expertise. The Order of St. John has succeeded in recruiting them for centuries. It continues based on requirement profiles to such an extent that today, there is a five-digit number of volunteer managers available in Europe at three hierarchical levels. At the top of the list is a leader appointed by the second hierarchical level, whose election is confirmed by the political leadership of the Federal Republic of Germany. This leader is highly motivated and has an outstanding personality. The prerequisite for this activity is a natural authority that works down to the hybrid construct's lower corporate and organisational levels. The Order of St. John has a special legal form as a legal entity and belongs to itself. The authority inherent in it requires obedience, which large profit-oriented companies also expected from their employees during industrialisation. This requires managers and employees to identify with the Order of St. John and trust the management (board). The board

can be compared to a cabinet and consists of proven experts, with the volunteers performing a task corresponding to their abilities. In their main office, each of these personalities is either the leader of a large company (major bank, insurance company, etc.) or has achieved outstanding scientific achievements. Board members identify, analyse and assess risks and formulate strategic objectives. The board is headed by a personality who is also the highest manager of the Order of St. John on an honorary basis. He coordinates the board's tasks, has the authority to issue instructions up to the lowest level and ensures the implementation of the goals set by the leader for the board. The middle hierarchical level is legally subdivided and run by volunteers and professionally successful persons committed to the upper hierarchical level by a promise of obedience. In addition, there are also legally dependent subdivisions at the middle hierarchical level, which are directly subject to instructions from the upper hierarchical level and are obliged to report to it. The lower hierarchical level of the Order of St. John is represented by ($n > 100$) companies, which are managed by volunteers and/or full-time employees, depending on the task and size. The majority of the employees work voluntarily and work in welfare work. On the other hand, full-time managers and employees are employed in corporations, which can be non-profit and non-charitable. The latter are sometimes commercially active service companies that support the non-profit sector regionally and nationally, such as catering, cleaning, IT and purchasing. It must be considered that the different and largely independent corporate units employ not only intrinsically but also extrinsically motivated employees who must be managed in a differentiated manner. A hospice director needs more empathetic leadership than the head of an accounting department. In the case of activities carried out directly on sick and elderly people, fewer dirigiste requirements may be given since these employees not only show above-average commitment in addition to their subject-specific vocational training but also feel called to their work. In the performance of administrative tasks, on the other hand, there is a more stringent organisational and management structure because these activities are carried out less out of vocation than out of the need for appropriate allocation and professional development opportunities. In this context, all companies of the Order of St. John have in common that an advisory board supervises their respective management. This advisory board is organised like the first and second hierarchical levels and comprises proven experts and prominent leaders. A rule that has been in force for centuries is: Never decide on implementing another institution in an area until it has been determined who will accompany the establishment and development as a professionally suitable volunteer. This ensures that a common goal serving the common good is pursued from the voluntary base to the hybrid top of the company. The types and activities described above require different leaders who can assume management functions and roles and fill them according to their human, conceptual and technical abilities. The lengthy search for such leaders is demanding and essentially does not differ in the intensity of the succession planning of a purely profit-oriented company. However, profit-oriented companies have the advantage of granting higher remuneration through corresponding performance-oriented additional variable remuneration components. This is impossible for non-profit companies, as the tax authorities check

the remuneration more intensively for appropriateness. The higher economic incentives are associated with greater pressure to succeed. However, it is not only about the companies' profits but also about the fact that their balances are linked to the successes or failures of the managers. Middle management and top management have been in office in large non-profit organisations in Germany for at least five years. Longer dwell times will not be noticeable in the foreseeable future. This is partly due to the different motivations of these employees and the growth structure of the management. However, a well-known disadvantage exists for larger non-profit companies under public law. Persons are assigned management functions for political or religious reasons, although they have neither a professional nor a human leadership qualification in individual cases. For example, municipal institutions at the city and district level fill management positions in hospitals, old people's homes and/or nursing homes with people they like, who often fail to the detriment of the facility.

2 Current State of Dealt Problems

This study analyses corporate governance challenges and how to overcome them in an increasingly complex and unpredictable world, based on the management of the Order of St. John that has been practised since the eleventh century. First, a structured literature search was conducted to understand proven coping strategies comprehensively. For this purpose, two search parameters were carefully selected and linked to asterisks and Boolean operators to determine the most relevant articles. The search parameters "Johanniter*" AND "Order of St. John" AND "Management*" were formed inductively to ensure that the filtered literature sources deal with the management methods used in the Order of St. John to overcome entrepreneurial challenges. In addition, the search parameter "obedience principle*" was formed deductively. The search based on the search parameters was limited to German-language and English-language literature sources to ensure the standardisation of the search results. The search was conducted on the Web of Science and Google Scholar without restricting the field of research to a wide range of disciplines and perspectives. The databases contained 74 literature sources. After carefully checking for duplicate search results and reviewing all document summaries, 17 literature sources were identified as particularly relevant and selected for further analysis. The selection processes in both databases were characterised by the fact that each literature source was thoroughly checked and evaluated according to the established criteria. This approach ensures that the literature sources used for this study provide an accurate picture of the research subject. In this context, the selected literature sources form a multi-layered perspective, encompassing quantitative and qualitative research methods.

2.1 Principle of Obedience

The principle of obedience is a central element of the Order of St. John's Order structure and is closely linked to its religious and chivalrous traditions. It reflects the primacy of discipline and strict adherence to the rules and commandments of the Order. This principle ensures efficient and disciplined organisation and leadership, which is essential for the Order's historical missions, such as caring for the sick and protecting pilgrims. Obedience in the Order means observing commands, spiritual devotion, and self-denial in serving one's neighbour and God. The principle of obedience is based on the idea that the members of the order submit to the will of the order's leadership and carry out their duties dutifully and obediently. The hospital brothers were obliged to obey the Master for Christ humbly. On the other hand, there was the Master's oath to observe the good customs and statutes of the Order, to decide the affairs of the Order only with the Council of the Brethren, and to comply with the decisions of the General Chapters. Accordingly, the habits made it clear that obedience to the Master extended to all areas but had its limits and conditions. These were found in the rules, statutes and good customs of the Order, as well as in the resolutions of the General Chapter. Obedience thus ended with instructions against the constitution of the Order. In the event of breaches of duty, every member of the Order could apply for a court hearing. Sarnowsky [11] at that time, the members of the Order needed to follow the leadership's instructions to ensure efficient and orderly nursing care. The definitions from 1900 to 1929 emphasised the control, centralisation of power, and domination of subordinates by the leader. Moore [12], Gutterman [13] even today, the principle of obedience in the Order of St. John is not understood as blind subordination. Instead, it is about the members of the Order respecting the decisions of the Order's leadership and loyally implementing them. The principle of obedience offers several benefits [14–16]:

- Quick decisions: A clear hierarchy and duty of obedience allow decisions to be made and implemented quickly. This is important in emergencies where quick action is required.
- Efficiency: The principle of obedience promotes the efficiency and effectiveness of the Order of St. John's work. By avoiding unnecessary discussions and disputes, resources and time can be saved.
- Unity: The principle of obedience contributes to the unity and cohesion of the Order of St. John. The Order members feel connected to each other because of their joint commitment to obedience.

The principle of obedience knows its limits. The members of the Order of St. John have the right to question decisions of the Order's leadership if they consider them wrong or immoral. In this case, they must communicate this openly and respectfully. The principle of obedience can also be found in the Order of St. John and other organisations, such as the military or the fire brigade. In these organisations, it is also essential that members carry out orders quickly and in a disciplined manner.

2.2 Management Methods

Although the autocratic model is considered traditional, some modern management approaches integrate elements similar to the principle of obedience to enable efficient and rapid decision-making. In addition, strong and centralised control is applied in a more modern organisational context. The literature search was, therefore, deductively supplemented by the following search terms:

1. Agile and classic management
2. Hybrid project management
3. Adaptive management
4. Flexible management
5. Combined leadership styles
6. Integrated management
7. Cross-functional management
8. Dual management approach
9. Mixed management methods
10. Cooperative management.

These methods combine traditional leadership principles with modern approaches to increase efficiency and employee motivation. One example is "Management by Objectives". Serrat [17] in this approach, managers and employees jointly define goals that align with the company's goals. This fosters a sense of ownership and commitment as employees are actively involved in goal setting. The principle of obedience comes into play here by setting clear, measurable goals and employees acting within these guidelines. Another example is "management by delegation" [18], in which tasks and responsibilities are delegated from the manager to the employees. Here, the principle of obedience is integrated by assigning responsibility for completing these tasks. Employees are given the freedom to decide and act within predetermined frameworks, which promotes self-reliance while maintaining the essential requirements and goals of the organisation. "Management by exception" [19] is another method that relies on obedience. Here, managers only intervene in exceptional cases and leave the day-to-day completion of tasks to the employees. This promotes the autonomy and personal responsibility of employees while, at the same time, ensuring that they will operate within the given guidelines and goals.

2.3 Hybrid Management

The principle of obedience is often used in hybrid forms in non-governmental organisations (NGOs). These hybrid management methods combine traditional leadership elements with contemporary and participatory approaches to increase organisational efficiency and employee satisfaction. This means that while top management sets clear guidelines and goals, team members and lower management have

more autonomy and decision-making power within these guidelines. The principle of obedience is not entirely abolished but used within a framework that allows for initiative and creativity. An example of implementing modern management methods that include the principle of obedience is the concept of "Empowering Leadership". Keith [20] employees are encouraged to contribute their ideas and make decisions independently as long as they align with the organisation's overarching goals and strategies. Managers focus on setting clear goals and framework conditions for team members to act. This promotes personal responsibility and can improve reaction speed to changing conditions. In addition, hybrid management models introduce agile methodologies that allow teams to respond flexibly to change while following an overarching strategy. Hasenbein [21], Schönbohm and Walter [22] and Brenner [23] these approaches foster a culture of continuous improvement and adaptation, especially for NGOs in a rapidly changing environment. The principle of obedience manifests in adherence to agreed processes and respect for roles and responsibilities within the team. Another element is the implementation of feedback loops and open communication channels. While obedience traditionally implies top-down communication, [24] modern hybrid methods promote a bidirectional flow of information. This allows ideas and concerns to be heard and considered by all levels of the organisation, improving decision-making and increasing the adoption of decisions. Hybrid management methods in NGOs encompass various approaches and strategies to make organisations more efficient, adaptable, and resilient, especially in the face of changing external circumstances such as shrinking civil freedom, as observed in NGOs in different countries. NGOs are employing strategies to deal with these challenges, including complying with local laws while maintaining their independence, building community support, strategic lawsuits, using digital media, and changing their scope of action to continue effectively without challenging the government. However, various obstacles, such as limited resources or political pressure, can constrain these strategies. Nevertheless, they offer valuable insights into what hybrid management approaches can look like in practice [25]. As described or applied in the literature, the concrete modern hybrid management methods depend strongly on an organisation's specific conditions and needs. However, the understanding of these methods remains partly abstract. Aboramadan [26] among the literature sources that know the principle of obedience, agile and adaptive management seem particularly noteworthy. While agile management is a combination of traditional management approaches, which typically incorporate the principle of obedience with clear hierarchies and instructions, [27] adaptive management is more conceptually oriented towards adaptability and change, thereby incorporating structures and strategies of the principle of obedience about adherence to policies and adaptation strategies within given limits. Heinrichs and Michelsen [28] the same approach is also taken by integrated management, combining different management styles and management principles. This also allows the principle of obedience to be integrated, especially regarding compliance with company processes. Siller [29] if the combination is limited to two management styles, it is also called the dual management approach. This refers to combining two different management styles, often combining traditional, hierarchical management (including the principle of

obedience) with more modern, flexible approaches. Prodoehl [30] similar to the dual management approach, combined leadership styles can mix elements of traditional leadership that emphasise the principle of obedience with other, more participatory styles. The concepts mentioned, such as flexible management, cross-functional management, mixed management methods and cooperative management, tend to focus more on collaboration, teamwork and flexibility and hardly directly involve the principle of obedience but can also include hierarchical elements in specific applications or within certain frameworks.

3 Methods

The literature review shows that the obedience principle of the Order of St. John can also be relevant in modern organisations. By integrating hybrid management approaches, organisations can reap the benefits of clear structures on the one hand while promoting flexibility and employee engagement on the other. In this context, to what extent this combination enables companies to respond effectively to complex challenges and adapt to changing circumstances is of interest. A group discussion procedure (GDP) is carried out to answer this research-guiding question. The GDP is a proven qualitative research instrument based on a long tradition of methodological foundation. In contrast to the individual interview, which aims at individual experiences, GDP provides greater access to collective attitudes and group orientations. GDP must be distinguished from other survey methods such as focus groups, group interviews or discussions. Although they also work with groups as survey units, they intervene in interactive dynamics during the survey and do not consider the speakers' references to each other in the data analysis. The most crucial premise of GDP is rejecting the idea that opinions, attitudes and orientations are predominantly formed within group discussion. From this perspective, the process is usually accused of deficiencies in terms of its reliability. Lamnek [31] only the documentary method, primarily based on Mannheim's sociology of knowledge, [32] led to the GDP now being understood as a representative interaction process of a group that draws on collective biographical experiences. This is not a content-related consensus on "WHAT" one thinks in the group based on one's own experiences, but rather an agreement on "HOW" the topic is talked about and "WHICH" relevant arguments are put forward at all. In this way, the GDP does not want to collect attitudes and opinions that can change shortly but rather to target groups' relatively stable collective orientation patterns and the issues that affect them. According to the methodological objective, the procedure requires consistency between the investigation unit, the moderation, and the evaluation. To answer the research question, the highest leadership of the Order of St. John was contacted in writing and asked for a GDP with three top managers of the Order (sampling). A qualitative-empirical GDP with three participants from upper management is possible but deviates from the usual recommendation of six to ten people. With only three participants, this homogeneous group is tiny, which can have advantages and disadvantages. The benefits

are that the exchange is facilitated due to similar experiences and perspectives, and each participant can express himself in detail. On the other hand, group dynamics and the exchange of opinions can be limited. With this in mind, the GDP was held on 29.05.2024 at 10:30 a.m. in the Order Center 12205 Berlin, Finckensteinallee 111. For the small group, the role of the moderator was of particular importance. He ensured that all participants had their say equally and that one person did not dominate the discussion (moderation). The recommended duration for group discussions is 01:00–01:30 h and was only slightly exceeded at 01:38 h. A structured guide guided the discussion and covered all relevant aspects. Mayring [33] the evaluation should have addressed the fact that the results might not be representative due to the small group size (data analysis). Instead of a GDP with three participants from upper management, individual interviews or a focus group study could have been considered an alternative. However, the GDP and the research questions were particularly suitable, as group-related interactions were also to be achieved. Horvath [34] finally, the findings were digitally recorded with a recording device (MP3 format) and transcribed (f4transkript). The transcript comprises a manageable amount of data with 37 pages, which does not justify using QDA software. For this reason, a category system was formed without distinguishing between parent and sub-categories.

4 Results

In the following, the individual categories and their findings are presented. Congruent paraphrases are thematically summarised in chapters of the second level of structure to comprehensively present the data used for the analysis. The attempt is made to sequence related contributions of the discussants (D) in lines of text (L) to compare them better. This summary also serves as a basis for further analysis [35]

4.1 Experiences of the Discussants

In the beginning, it is primarily about determining basic information. For example, there should be no interpretation of experiences already made, even if this cannot and should not be ruled out during the GDP. Instead, it is a matter of clarifying from which side of experience the discussant in question approaches the topic:

The parents should have prepared the discussants for their offices (D1: L. 6–10). However, the Order of St. John played a role in the family circle (D2: L. 294–298). The Master of the Order of St. John is supported by two essential supporters, the Chancellor of the Order and the Secretary-General (D1: L. 60–62), without the Master intervening operationally (D1: L. 125–129). The Chancellor of the Order joined the Order of St. John in 1981 and, in addition to several years of voluntary service in the Johanniter Unfall Hilfe (D2: L. 299–301), can look back on the exercise of various functions (D2: L. 302–308). In addition, as an emeritus and retired professor of

economics, he worked for many years in university education (D2: L. 237–239). At his university institute, he led a team of 20 to 30 scientists, with whom he had one hundred 100 per cent confidence (D2: L. 244–246). The Secretary-General began his professional career 23 years ago in the Order of St. John as an employee of his indirect predecessor. At that time, there was no corporate structure, but the hospitals and geriatric care facilities were individual institutions or companies owned by the religious cooperative (D3: L. 332–348).

All three leading employees and functionaries of the Order of St. John have learned their work from the bottom up. Their parents predetermined their memberships in the Order of St. John. The master is less responsible for operational decisions than for strategic decisions. In doing so, he can reliably rely on the treasurer and secretary general of the Order of St. John. The word "trust" runs like a red thread through the descriptions. The Chancellor of the Order and the Secretary-General justified their trust. Experience was gained in essential functions as treasurer or business manager and during stays abroad (D2: L. 249–251). Time-outs for raising children were not an obstacle (D2: L. 301–304) when this was not yet opportune. This shows that the Order of St. John was already ahead of its time.

4.2 Interactions Between the Discussants

In the following, the group-related interactions between the discussants are analysed in more detail:

In the interactions, it becomes clear that the discussants confirmed each other (D2: L. 256–257) or obtained confirmation before their speech (D3: L. 574).

Acknowledging other participants in a discussion or obtaining confirmation before one's speech has several meanings and functions. Confirmations can signal agreement with the statements of others. They also contribute to a positive and constructive atmosphere for discussion. Affirmations show that you are actively listening and appreciating the contributions of others. In addition, they can consolidate their argumentation. Affirmations can also help avoid misunderstandings and work out common points of view. This can contribute to consensus-building in the discussion. On top of that, getting endorsements shows respect for the opinions of others. It signals the willingness to respond to the perspectives of others. Ultimately, confirmations and inquiries can directly address and clarify ambiguities or misunderstandings. It is important to note that excessive confirmation or constant obtaining of confirmations can also be perceived as insecure or disturbing. This was not to be observed in the present GDP. Instead, a balanced communication strategy was used, which promoted an effective and respectful discussion.

4.3 Right to Give Instructions and the Principle of Obedience

The principle of obedience in the Order of St. John reflects a balanced mix of traditional values (unity of the Order, Christian faith, etc.) and modern requirements (quick decisions in a BANI environment). The extent to which the efficiency of the Order of St. John, in which critical reflections and ethical reflections are permitted, is now to be analysed:

The right to give instructions on the one hand and the principle of obedience on the other are compared to a sword, which can not only become blunt if used too often but whose actual use is also dangerous. To avoid wanting to open Pandorra's box, the Order of St. John never insisted on the right to give instructions or the principle of obedience (D1: L. 149–155). Regardless of an apparent association, the described sword is not perceived as the sword of Damocles (D1: L. 160–162). Regarding satisfactory performance and the observance of uncoded rules of mutual trust, the right to give instructions and the principle of obedience only resonate in the background (D2: L. 174–177). This is different from uniformed units (police and army), where there are clear command structures (D2: L. 222–226). Consequently, the principle of obedience in the Order of St. John is understood more as an art of steering with gentle and clear signals (D2: L. 256–268). Such signals can come from formulations without doubt about underperformance but are presented appreciatively (D2: L. 270–273). Managers should treat their employees decently (D1: L. 437–442). This is not an expectation but a demand on managers. In this respect, it is not only about the professional but also about the personal-social competence of managers (D3: L. 444–447).

Performance and trust are in a complex tension with each other, which plays a vital role in different contexts, especially in the work environment. The Order of St. John recognises that a one-sided focus on performance metrics can be problematic. A purely performance-oriented culture can lead to the promotion of toxic leaders. Instead, Johanniter advocates considering trust as an equal or even more critical criterion alongside performance. Trust and performance do not necessarily have to oppose each other. Trust can increase performance. Trust is also essential for successfully coping with change in the Order of St. John. Trust enables flexible action and increases adaptability. In summary, a balance between performance orientation and confidence-building should be sought. Companies and organisations should, therefore, create evaluation and development systems that adequately take both aspects into account and reconcile them.

4.4 Challenges

The current challenges for companies and organisations require a rethink in corporate culture and among managers to create the conditions for more sustainable success in a BANI environment:

Like all companies and organisations, the Order of St. John has to cope with financial, personnel, and organisational challenges. It is not out of the question that the current challenges are more significant than ever before (D2: L. 535–543). The challenges are not more important but have changed (D2: lines 544–546).

Another aspect is that optimisations are always carried out under secondary conditions. In mathematical terms, there is an objective function and conditions under which one works. Companies and organisations strive to optimise earnings, return on sales and market share, driven by the typical economic criteria by which the success of a company and an organisation is measured. In addition, companies and organisations have to contend with ancillary conditions. It's different from the Johanniter. They do not operate to be the most prominent social service provider in Germany and/or to make the most significant profit. The Knights of St. John have a double mission to fulfil, which, on the one hand, consists of providing help to those in need regardless of ideology, religion and skin colour and, on the other hand, strengthening the Christian faith. The guarantor is the Knighthood of the Order of St. John (D2: L. 546–562).

Although opinions can be mapped and analyses produced relatively quickly from the knighthood's network, the success factor and claim of the Order of St. John is the combination of Caritas, welfare and logistics. In principle, this is expected of the Order of St. John and every member. Of course, this requires structured strategy development that formulates the claim to face the challenges of the social market economy and to support and further develop the operational business without running into bottlenecks. Regardless, there are still enough everyday problems that a qualified management has to deal with (D3: L. 584–607).

The exciting thing about the Order of St. John is the balancing act between tradition and modernity. There is much potential in tradition, which allows us not to act in the spirit of the times and not to develop new business models frantically. It is essential to help on a Christian basis and to do the right thing from a Christian perspective (religious mission). Volunteering and the employees, some excellently trained, play an essential role in this. Without the members, functionaries and their expertise (bank executives, economic advisors, lawyers, military personnel), the Order of St. John would be less successful. This is an enormous potential for people willing to get involved beyond the average level and can do so with great competence. Nevertheless, the Order of St. John has problems concerning merging areas and the creation of synergies (D1: L. 620–643).

Other challenges include selecting and filling independent management functions and the challenges the selected managers face. Finally, leadership deficits can also be seen among the Knights of St. John (D2: L. 803–810), who nevertheless have a high level of identification with their order (D3: L. 727–761).

Despite the numerous challenges, artificial intelligence (AI) is treated ambivalently in the Order of St. John. In the hospitals and retirement homes of the Order of St. John, AI is just as big a topic as it is among the employees and the membership administration (D1: L. 1021–1024). On the other hand, the leadership of the Order of St. John believes that AI will not change much. Leadership is understood, on the one hand, as a reaction to surprises and, on the other hand, to think in advance. Both

belong together and cannot be taken away by the AI. This is also not a game of chess, where one can plan from the first to the last move, but an opponent always makes a different move than expected and whom one has to anticipate (D2: L. 1060–1078).

The Asian board game Go is 3000 years old and has an even higher number of moves than chess, so it was long considered impossible to predict individual moves by AI. As a result, averagely good Go players regularly won against above-average AI until analysts came up with the idea of programming AlphaGo with man's 30 million smartest moves. This made AlphaGo so good that the program won four to one against the then-reigning world champion, Lee Sedol. This led to the question of whether the programming data was based on the best moves. The idea was born to have two AIs, which only know the rules of Go, play against each other 29 million times and learn from each other (AlphaGo Zero). Both programs subsequently competed against each other, and AlphaGo lost 0–100 against AlphaGo Zero. This leads to the conclusion that humans have been playing Go for 3000 years without understanding the gameplay and that there are still surprising insights lurking in AI.

5 Discussion

The discussion here deals with the article's findings, challenges, and implications for practice. Both the topic-specific literature and the transcript of the GDP are taken into account. This shows that hybrid management combines traditional (hierarchical) structures and flexible, agile approaches. This hybridity allows nonprofits to leverage both the stability and control of hierarchical systems and the adaptability and innovation of agile methodologies. A central example is the implementation of agile project management methods within a structured, bureaucratic framework organisation. A key benefit of hybrid approaches in nonprofits is improved responsiveness to external changes and demands. Nonprofits often have to respond to uncertain funding sources, changing policy frameworks, and changing target audiences' needs. Hybrid management enables faster and more effective adaptation to these challenges. In addition, hybrid structures promote employee participation and motivation. By incorporating agile methods, employees gain more autonomy and responsibility, leading to higher satisfaction and greater identification with the organisation. A significant advantage of hybrid structures is that they can mitigate conflicts, as all organisation members understand that instructions must be followed and hierarchies must be respected. It should be noted that all regulations must be fully complied with by non-profit and non-profit organisations. However, the introduction of hybrid management is not without challenges. One of the biggest hurdles is cultural change within an organisation. Employees and managers must be open to new ways of working and be willing to break down traditional hierarchies in favour of a more flexible and agile way of working. This requires extensive training and ongoing support. Another problem can be the integration of different management methods. Coordination and alignment between traditional and agile teams require clear lines of communication and high transparency. Without careful planning and implementation, conflicts and

inefficiencies can arise. This means nonprofits adopting hybrid management should take a systematic approach. This includes assessing the current organisational structure, identifying areas where agile methodologies can be introduced, and developing a comprehensive change management plan. Continuous training and support for employees are also crucial for the success of hybrid approaches. Leaders should act as role models and actively communicate and promote the benefits of hybrid methods. In conclusion, hybrid management represents a promising approach for non-profit organisations to meet their environment's complex and dynamic demands. Through proper implementation and continuous adaptation, these organisations can increase their efficiency and improve their ability to innovate and adapt.

6 Conclusion

The present study provides valuable insights into the effectiveness of hybrid management approaches that combine traditional hierarchical structures with modern agile methods. A key finding of the study is that hybrid management approaches enable a flexible and efficient response to challenges faced by non-profit organisations. These approaches combine clear hierarchies and structures with high employee autonomy and participation. This leads to higher employee motivation and satisfaction, as employees are actively involved in goal setting and have more personal responsibility. In particular, the Order of St. John's principle of obedience, which is based on discipline and strict adherence to rules and commandments, is integrated into modern management methods such as "Management by Objectives", "Management by Delegation", and "Management by Exception". These methods promote the efficiency and effectiveness of the organisation by setting clear, measurable goals and giving employees room to manoeuvre within those targets. The study highlights the benefits of hybrid management approaches, including improved responsiveness to external changes and demands. Nonprofits often have to respond to uncertain funding sources, changing policy frameworks, and changing target audiences' needs. Hybrid management enables faster and more effective adaptation to these challenges. A significant advantage of hybrid structures is mitigating conflicts, as all organisation members understand that instructions must be followed and hierarchies must be respected. Hybrid management approaches cannot be introduced without difficulties in every case. One of the biggest hurdles is cultural change within an organisation. Employees and managers must be open to new ways of working and be willing to break through traditional hierarchies in favour of more flexible ways of working. This requires extensive training and ongoing support. Another problem can be the integration of different management methods. Coordination and alignment between traditional and agile teams require clear lines of communication and high transparency. Without careful planning and implementation, conflicts and inefficiencies can arise. This means nonprofits adopting hybrid management should take a systematic approach. This includes assessing the current organisational structure, identifying

areas where agile methodologies can be introduced, and developing a comprehensive change management plan. Continuous training and support for employees are also crucial for the success of hybrid approaches. Leaders should act as role models and actively communicate and promote the benefits of hybrid methods. Another important aspect highlighted in the study is trust within the organisation. Trust is considered an equal, if not more critical, criterion alongside performance. A one-sided focus on performance metrics can lead to the promotion of toxic leaders, while trust increases flexibility and adaptability. This is especially important for successfully managing change and fostering a positive organisational culture. In conclusion, hybrid management approaches are a promising way for nonprofits to meet their environment's complex and dynamic demands. Through proper implementation and continuous adaptation, these organisations can increase their efficiency, innovation, and adaptability and thus fulfil their charitable mission more effectively. The Order of St. John serves as an exemplary model for successfully integrating traditional values and modern management methods, which can inspire and guide other non-profit organisations.

7 Limitation

A significant limitation of the study is the limited generalizability of the results. The investigation focuses on the Order of St. John, a—absolutely—specific non-profit organisation with unique historical and structural characteristics. Although the findings can be valuable for similar organisations, caution should be exercised against extrapolating these findings to other nonprofit or for-profit organisations. The specific conditions and cultural specificities of the Order of St. John may limit the applicability of hybrid management approaches in different contexts. The study is based on analysing documents about the Order of St. John and GDP. While this qualitative data allows for deeper insight and understanding of organisational dynamics, a lack of quantitative data will enable broader statistical validation of the results. In addition, the GDP was carried out with a relatively small and homogeneous group of three top managers of the Order of St. John. A more extensive and diverse sample could provide a more comprehensive picture of the different perspectives and experiences within the organisation. In particular, involving employees from different hierarchical levels and functional areas could provide additional valuable insights into the challenges of implementing hybrid management approaches. The study acknowledges this but offers limited practical guidance on addressing these challenges related to organisational cultural change. The shift from traditional hierarchical structures to more flexible, agile ways of working requires training and support and a profound cultural shift that often encounters resistance. More detailed strategies and best practices to promote this change would be helpful. Nevertheless, external factors and environmental influences that influence the organisation are considered, such as political conditions and economic uncertainties. However, there is limited discussion of how these external factors specifically influence the implementation and success of

hybrid management approaches. Future investigations could focus on analysing these influences and developing strategies for adapting to changing external conditions.

Appendix

Attached are two documents.
The data corpus contains the following contents:

- GDP guide
- Transcript.

The appendices are available at the following link:
https://doi.org/10.17605/OSF.IO/MU38R.
The appendices can also be accessed via the following DOI:

https://doi.org/10.17605/osf.Io/mu38r

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The Influence of Marketing Factors on the Attractiveness of Sport

Branislav Nedbálek and L'udmila Gregušová

Abstract The aim of our work was to examine the factors influencing the attractiveness of sport and expand our knowledge in this area. We wanted to determine the importance of these factors, analyse their mutual relationships, and identify their relationship with other characteristics such as sociological, psychological, and philosophical properties of people. Through our research, we confirmed the existence of mutual relationships between the factors influencing the attractiveness of sport and showed that these factors are related to the properties mentioned above. Based on these findings, we created market segments and identified determinants of behavior within these segments. To ensure the practical use of our results, we created a table that integrates the acquired knowledge. This table can serve as a tool for all those involved in the field of sports marketing. We hope that our findings will contribute to theory and practice and help increase the attractiveness of sports for various population groups.

Keywords Sport · Marketing · Segmentation · Sport attractiveness · Market segment

1 Background

The attractiveness of sport is a phenomenon of interest to many of the councils not only interested but also the general public. Why is sport so attractive to people, why do we perceive significant differences in the attractiveness of individual sports, why does interest in sport often fluctuate? This is of interest not only to sports officials, but also to the athletes themselves and also to the sports public. This seemingly simple question "why?" is also being asked by us in our efforts to penetrate the marketing of sport. Experience in elite sport helps us understand many things that are not familiar

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at first glance. However, we know that the economic side of sport has a significant impact on its success, which can subsequently be improved by effective marketing, which is crucial for all parties involved.

Our analysis of the influence of marketing factors on the attractiveness of sport aims to deepen knowledge that has not yet been properly developed, although research has moved considerably.

1.1 Aim of Review

The aim of our work was to examine the factors influencing the attractiveness of sport and expand our knowledge in this area. We wanted to determine the importance of these factors, analyse their mutual relationships, and identify their relationship with other characteristics such as sociological, psychological, and philosophical properties of people.

Based on these findings, we created market segments and identified determinants of behaviour within these segments.

To ensure the practical use of our results, we created a table that integrates the acquired knowledge. This table can serve as a tool for all those involved in the field of sports marketing. We hope that our findings will contribute to theory and practice and help increase the attractiveness of sports for various population groups.

2 Introduction

Knowing the context of sport's appeal has been key since time immemorial when creating a marketing plan. Finding out how consumer behavior works, what trends and motives it is subject to is a fact without which successful sports marketing cannot be done.

The development of new sports products and subsequent presentation of products to the public, its correct timing and chosen marketing strategy stands or falls on the most consistent knowledge of the desires and requirements of the customer. Despite the fact that in the period after 2015 there is a significant shift in the field of sports marketing, in our opinion it is still possible to go more in-depth, especially by identifying a greater number of factors influencing the shopping behavior of sports to the lusty public. In our work, we managed to gather a number of factors that allowed us to gain a deeper understanding of the issue, but at the same time led to a number of other questions. It was particularly surprising to find that the relevance of individual factors related to the attractiveness of sport was not yet known. Many of them appear to be in a rather contradictory position, pointing to the need for segmentation in the field of sports marketing, it is crucial to understand the relationship between the attractiveness of sports and its successful sales. Understanding customer preferences, trends, and motivations is necessary for successful marketing of new sports products.

Although the approach to sports marketing has changed since 2015, there is still room for a deeper understanding of the factors influencing the decisions of sports fans. A significant number of factors were identified in the preliminary research, but in many cases, they are contradictory, requiring segmentation. After examining the differences between sports fans based on these factors, it is necessary to understand the relationships between these fans and other characteristics, such as philosophical, psychological, or social factors. This is especially important for gaining insights into the market from multiple perspectives and establishing a foundation for appropriate marketing strategies. From the above, it follows that research should contribute to understanding the complex relationships among individual factors that impact the attractiveness of sports from a marketing perspective and their practical applicability. These are questions that arise from the actual practice itself.

A better understanding of the psychology of the audience, the creation of products that resonate with them, and the subsequent communication of a product that fulfills the audience's needs will undoubtedly support the growth of sports popularity on a societal scale.

3 Current Research Trends in Slovakia and Abroad

3.1 Research in Slovakia

In Slovakia, there has been intense discussion about the influence of marketing factors on the attractiveness of sports in the last decade. Several studies have demonstrated that marketing activities have a significant impact on the perception of sports events and teams, and that successful promotion and presentation of a sports event can increase its attractiveness and popularity.

A research study conducted by Kozáková et al. in 2017 focused on the influence of marketing factors on the popularity of sports teams in the Slovak Republic. The researchers collected data from nearly 900 respondents who were fans of different teams. The results showed that team success and performance on the field had the greatest impact on team popularity. However, the importance of marketing factors increased with the age of the fans. Additionally, the team brand was important for younger fans, while older fans valued the team's quality more.

In 2019, a study was conducted on the impact of marketing factors on attendance at sports events in Slovakia. Researchers Mihaliková and Bačíkova collected data from 500 respondents who attended a sports event in 2018. The results showed that the quality of marketing communication had a significant impact on the respondents' decision to attend the event. It was also important that fans felt greater satisfaction with the event when competitive and interesting environments, in which the event took place, were showcased in advertisements.

At the international level, a lot of research is also dedicated to studying the impact of marketing factors on the attractiveness of sports. In this section of the chapter, we will look at some examples of research by foreign authors.

A study conducted by Mahmood Khan et al. in 2018 focused on the influence of marketing factors on the perception of sports teams in the United States. The results showed that not only team success but also the brand and reputation of the team were important. Marketing activities such as sponsorships and team promotion had a significant impact on the overall attractiveness of the team. Furthermore, the research showed that the team's social impact, such as its involvement in charitable activities, was important.

In 2019, a study was conducted on the influence of marketing on popular European football leagues, conducted by Zeng, Tian, and Xu. The results showed that marketing factors such as the quality of marketing communication and sponsorships had a significant impact on the overall attractiveness of the league. Additionally, the research showed that league popularity increased when the league had more visibility on social media and had a quality digital platform. "In 2020, a study was conducted on the impact of marketing factors on the popularity of sports events in Australia. Researchers Kim and Chalip collected data from 500 respondents who attended a sports event in Australia. The results showed that the quality of marketing activities had a significant influence on the respondents' decision to attend the event. The study also showed that the perceived social status of the event was important and could have an impact on visitors' decisions.

Studies in Slovakia and abroad have shown that marketing factors have a significant impact on the attractiveness of sports. The impact of marketing is manifested in various aspects, such as team popularity, event attendance, as well as brand perception and team reputation.

3.2 Marketing

There are countless definitions of marketing, but the most concise one is as follows: "Marketing is a managerial discipline that deals with creating value for customers and other stakeholders in the exchange process. It is a set of processes that include market research and analysis, product and service design, pricing, communication, and distribution, with the goal of meeting customer needs and achieving business objectives" [1].

This definition emphasizes the key elements of the process, including analysis, research, planning, and implementation of concepts, creating value for customers, and building customer relationships.

The following definition is very simplified, but it still captures the essence of marketing in relation to customers who provide companies and organizations with profit. "The goal of marketing is to fulfill and satisfy the needs and wants of a target group of customers through the creation, promotion and exchange of products and value with them" [2].

If we attempt to characterize the essence of marketing in the simplest and most understandable way, we come to the realization that marketing serves to identify and satisfy human needs through change and with the help of tools such as marketing research and the marketing mix.

Marketing significantly differs from ordinary sales of goods in its concept. While sales aim to compel customers to purchase the goods that a business has already produced, marketing strives for the business to produce and sell the goods that customers demand. This is achieved by identifying their needs and desires and adapting products, as well as their price, sales methods, promotion, design, packaging, and other factors to meet those needs and desires.

There are various contradictory views on the period of its emergence, but it is undeniable that if we consider the mentioned definitions of marketing, similarly oriented human behavior must undoubtedly have a long history. Some authors describe marketing as a social institution whose essence lies in satisfying people's needs. They do not identify it solely with the execution of specific activities [3].

Despite the evidently long existence of marketing behavior, the impact of social, cultural, and economic changes at the beginning of the twentieth century led manufacturers and sellers to focus on market needs. "The market is a social institution that regulates exchange relationships between buyers and sellers, and the price mechanism is one of the key coordinating mechanisms that help align supply and demand" [4].

We believe that there is a parallel between the changes in the economic environment in European countries at the end of the twentieth century and the situation in Slovakia in the field of sports, which is gradually starting to be governed by economic principles. Therefore, the importance of marketing is gradually increasing, as was the case in Western Europe at the end of the twentieth century.

Internationally recognized experts in marketing, Philip Kotler and Gary Armstrong, further define marketing as "a social and managerial process by which individuals and organizations obtain what they need by creating, offering, and exchanging products and services of value to others" [5].

However, the creation of a marketing team within an organization itself does not have a significant impact on increasing the organization's revenue. However, there is an assumption that if marketing behavior is implemented throughout the entire organization, meaning in the actions and behaviors of individual departments, individuals, and officials, it will inevitably have a favorable effect on the overall revenue of the organization.

Kotler et al. [5] further define marketing as "a social and managerial process through which individuals and groups satisfy their needs and desires in the production and exchange of products or other values." This definition acknowledges the needs and desires of consumers. It emphasizes a managerial approach to marketing and the need for a marketing program that covers aspects of the marketing mix. It highlights the need for promotion to attract demand [5].

The definition of marketing also encompasses people's desires and needs, which are seen as opportunities. When applying this definition to sports, it implies that if, for example, we want spectators to attend matches and purchase club merchandise, or

if we want to acquire a new sponsor for our team, we must satisfy their requirements, whether through the experience of the match or through media exposure for sponsors. The goal is to create a product that people demand, so there is no need to artificially create any need.

According to Schichor, it is worth mentioning that the aim of marketing is also to ensure long-term customer satisfaction, as only that can secure prosperity for a company [3]. According to Kotler and Armstrong [6], customer satisfaction is defined as "the difference between customer expectations and the actual product received" [6].

3.3 Sports Marketing

Sports marketing refers to a set of strategies focused on marketing and distributing products and services in a sports context. When discussing this type of marketing, it is necessary to distinguish between the promotion of sports events and entities and the dissemination of brands or products through these events and entities. Bernard [7] defined it as follows: "Sports marketing consists of all activities designed to meet the needs and wants of consumers in the exchange process. Sports marketing aims to enhance two fundamental aspects: marketing sports products and services to consumers and marketing other consumer and industrial products through sports advertising." Based on these definitions, it is important to differentiate between "sports marketing" and "marketing through sports" [7].

As Mullin et al. [7] further explain, sports marketing deals with the marketing of sports activities themselves, while marketing through sports refers to the use of sports to promote other products, such as through advertising [7].

The aim of sports marketing is the promotion of physical activity, sports activities, and a healthy lifestyle, which, in our opinion, is evidence of the usefulness of marketing itself.

4 Objectives, Hypotheses, and Tasks of the Research

Currently, in addition to organizations active in the field, the state also plays a role, to a greater or lesser extent, in popularizing sports as a whole. Its goal is to minimize negative phenomena in our society. This fact highlights the necessity of developing theory in this area and the need for the creation of a system that enables the utilization of acquired knowledge in an effort to suppress negative trends.

4.1 Objective of the Research

The objective of the research is to analyze and subsequently evaluate the impact of relevant factors influencing the attractiveness of sports from a marketing perspective on diverse population groups.

These factors will subsequently serve as a starting point for determining the determinants of behavior within created market segments in relation to sports and its various sectors.2.2 Hypotheses of the research work:

H1: We assume that the factors influencing the attractiveness of sports from a marketing perspective are sufficiently different and have varying importance, which will allow us to create homogeneous groups based on them.
H2: We assume that there is a close relationship between the selected factor influencing the marketing attractiveness of sports and other factors influencing this attractiveness.
H3: We assume a correlation between the chosen factor and the psychological, sociological, or philosophical aspects of an individual.
H4: We assume that there is a relationship between the preferences of individual market segments and the nature of specific sports disciplines.

4.2 Objectives of the Research Work

U1: Identify and analyze the factors that directly influence the marketing attractiveness of sports from a multitude of factors.

U2: Identify relevant factors suitable for market segmentation. Subsequently, divide the market into homogeneous groups based on these factors.

U3: Analyze the relationships between individual factors influencing the attractiveness of sports from a marketing perspective and analyze the preferences of created market segments in relation to these factors.

U4: Analyze the relationship between different factors influencing the attractiveness of sports and the psychological, sociological, or philosophical characteristics of individuals.

U5: Create a comprehensive element that integrates the acquired knowledge and can be practically utilized based on the priorities and characteristics of individual sports sectors.

4.3 Methodology of the Research Work

In the following chapter, we will provide the necessary theoretical foundation for addressing the issue related to the impact of marketing factors on the attractiveness

of sports, and we will also describe the fundamental concepts that we will continue to work with in our study.

Marketing in the context of sports typically refers to the process of creating, communicating, and delivering value to the customer in relation to sports products and services. Its goal is to increase interest in sports, enhance the attractiveness of sports events, increase participation in sports events, improve brand awareness in sports, and generate revenue from these activities.

Various methodologies are employed in examining the impact of marketing on the attractiveness of sports, which vary depending on the objectives and nature of the research. Some of the most commonly used methodologies include:

Surveys and questionnaires: Surveys and questionnaires are a common way to gather data on the perception of sports and its attractiveness. Respondents can include fans of a particular team, participants in sports events, or the general public. Survey questions may address aspects such as event experiences, brand importance, satisfaction with advertising and sponsorship.

Observational studies: Observational studies are used to gather data on behavior and reactions to marketing activities, such as stadium or television screen advertisements, or social media activity. Observers observe how respondents react to a given activity and record their behavior and responses.

- Experimental studies: Experimental studies focus on testing hypotheses and determining causal relationships between marketing activities and the attractiveness of sports. For example, participants may be exposed to different advertisements or brands and then asked to evaluate the attractiveness of a sports event or team.
- Analysis of data from digital channels: The modern era is influenced by digital technologies used for the promotion and marketing of sports. Therefore, the analysis of data from digital channels such as social media, websites, and applications is increasingly utilized. This approach provides insights into interactions with fans and the public, as well as which marketing activities are most effective.
- Case studies: Case studies involve in-depth examination of specific cases and situations. For example, a study may focus on a sports team or event and analyze how it has succeeded.

4.4 Determination of the Research Situation

The research stages were as follows:

- The first stage was dominated by market analysis, which involved analyzing people, their opinions, attitudes, and motivations related to engaging in specific sports activities or activities associated with sports. Subsequent evaluation of known factors and assessment of their importance.
- Based on the identified factors, the population was segmented using post hoc segmentation, which also allowed us to identify characteristic features of each group.

- In the final stage, we created a systematic element that summarizes and connects the acquired knowledge.

4.5 Characteristics of the Sample

The research sample was highly diverse in terms of gender, age, inclination towards sports, socioeconomic status, etc. From a regional perspective, we chose the Banská Bystrica region based on its population diversity.

Regarding the distribution of questionnaires, we followed the criteria of the social model (Foret and Stávková) from 2003 and used intentional quota sampling of respondents.

4.6 Methods of Data Collection

- Questionnaire

Our aim was to characterize the market in a broad spectrum using a questionnaire. The questionnaire was distributed partially in printed form and partially online. Its response rate was at the level of 78%, which can be considered a success. The survey was conducted from 11/2019 to 08/2022. By utilizing the obtained information, it was possible to define criteria for segmenting the market into homogeneous segments. We identified key characteristics such as psychological, philosophical, or social aspects closely related to sports.

4.7 Data Processing and Analysis Methods

During the processing and analysis of the acquired data, we employed not only logical methods such as analysis, synthesis, inductive and deductive approaches but also standard mathematical and statistical methods. In particular, we utilized frequency distribution, its percentage representation, and chi-square test.

4.7.1 Question Areas

The first set of questions focused on determining factors from the respondents' perspective. In the following tables, we present the frequency of certain responses with the highest value highlighted, along with their percentage representation. Out of the total of 35 factors considered, we present the frequency distribution of 28 factors.

5 Distribution of Factors in the Research Sample

In our preliminary study, we focused on identifying various factors influencing the attractiveness of sports from a marketing perspective. While our questionnaire with open-ended questions revealed a large number of these determining factors, initially, we couldn't determine their individual relevance. As expected, their frequency of occurrence varied, resulting in different levels of importance for these factors. Our research enabled us to make precise quantitative evaluations.

We organized the factors according to their relative importance. This information was crucial for us, so we asked respondents to rate each specific factor on a scale from one to five, where four and five represented important and very important, respectively.

The top-ranking factor in our list was "personal involvement" (Fig. 1). In fact, our preliminary study already indicated the immense significance of this factor in the attractiveness of sports itself. The frequency of responses with values of four and five accounted for 400 (55%), which is over half of the sample. We also observe that we have the highest absolute number of responses with a value of five (32.5%).

We can see that for almost one-third of the respondents, it is important whether they have had some connection with the sport in the past, whether actively or passively as spectators or within their family.

Also, from the graph (based on the frequency of values one and two), it can be inferred that only 18% of respondents do not consider this factor to be of great importance.

In our opinion, besides encompassing the element of personal involvement, this factor also integrates other elements such as knowledge of the rules or mastery of sports techniques. This factor draws attention to the urgency of the mentioned components.

In second place, the factor of "socialization and friends" emerged (Fig. 2). It is natural, as socialization is deeply rooted in human needs, and sports provide us with the opportunity to actively or passively spend free time with friends.

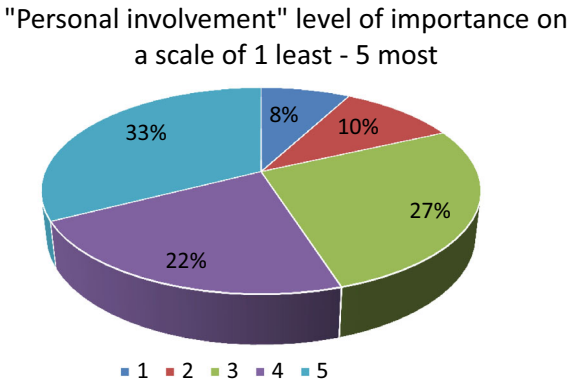

Fig. 1 Personal involvement. *Source* Own processing

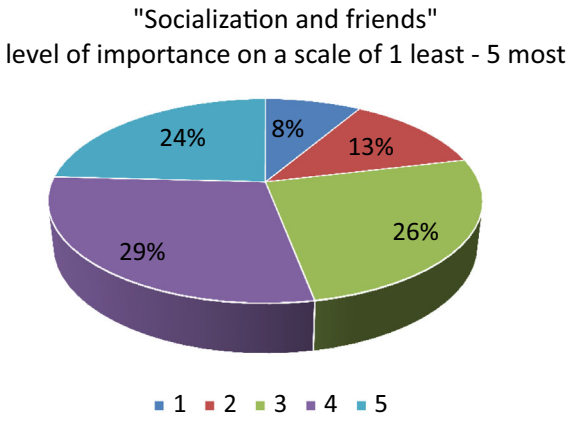

Fig. 2 Socialization and friends. *Source* Own processing

Values four and five are relatively equally represented in this factor, indicating its high importance in public perception.

A total of 388 (53%) respondents consider this factor as important or very important (values four and five). Therefore, we understand socialization as an essential factor for sports. In other words, people choose sports based on various criteria, but they engage in them not because of friends. However, they enjoy spending time with them on the sports field, as indicated by the graph with a relatively high frequency of value three.

In third place, respondents ranked the factor of "technical skills and tactics" (Fig. 3) based on their answers. Values four or five were represented in a ratio of 51%. Only 17% of respondents consider this factor unimportant. This finding is particularly interesting in the context of the growing e-sports phenomenon, as unexpected situations requiring complex solutions in a short time frame often arise in this domain.

It is also important to note that people perceive not only the physical but also the intellectual aspect of sports, the so-called path to achieving a goal. It should be

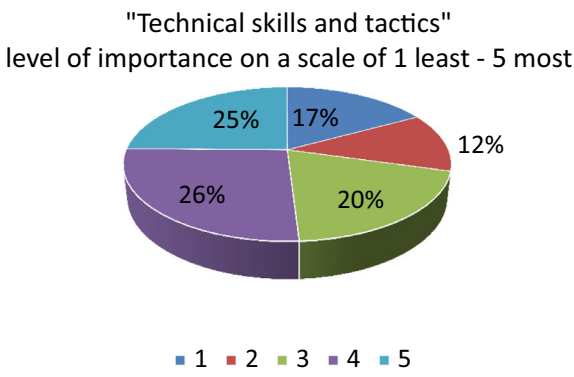

Fig. 3 Technical skills and tactics. *Source* Own processing

mentioned that the technical and tactical factor must be somewhat comprehensible even to a layperson because many sports that an uninterested spectator may not be familiar with have highly complex techniques and tactics. We especially refer to the rapidly evolving sphere of e-sports.

These chosen factors are just sample for the purpose of this article. Now we are going to present research results for.

5.1 Distribution of Factor Importance from the Perspective of Different Groups

The published graphs and data so far relate to respondents as a whole, i.e., the population in the Banská Bystrica region. We have obtained a wealth of valuable data that not only revealed many unknown aspects of consumer behavior related to sports but also provided important information for practice. However, these data are primarily suitable for use in "mass marketing." It is still unknown how the various groups of sports spectators differ and on what basis we would be able to create coherent segments, understand elementary differences, and so on. It is evident that this presents numerous possibilities for practical applications.

It is crucial to accurately identify and thoroughly understand the group we are targeting with our communication efforts. Therefore, the following chapters assess different groups of sports spectators from various perspectives. The subsequent segments are divided based on the characteristics of sports and the attributes associated with individuals. Of course, there are many possibilities for segmentation, but we have attempted to create a comprehensive system based on the characteristics of individual sports disciplines as well as human attributes that are relatively easy to comprehend and also applicable in sports.

Within these segments, there are factors that influence the attractiveness of sports in the eyes of each segment. Due to their importance or deviation from the overall population, we focus only on those factors that we consider relevant. This means that we specifically examine those factors that exhibit significant deviations from the overall population or are important for specific sports.

We have selected segmentation factors that have been shown to be generally important (based on their weight) or are useful for individual sports disciplines.

In the following chapter, we describe the created segments, their importance, and deviations from the overall population, which is crucial for practical application.

We also aim to confirm or refute hypotheses number two and three, which suggest a relationship between the selected factor and other factors. For example, we can attempt to confirm or refute the following hypothesis: "An increase in the demand for socialization in the population affects the need for personal engagement." There are, of course, several similar examples within the text.

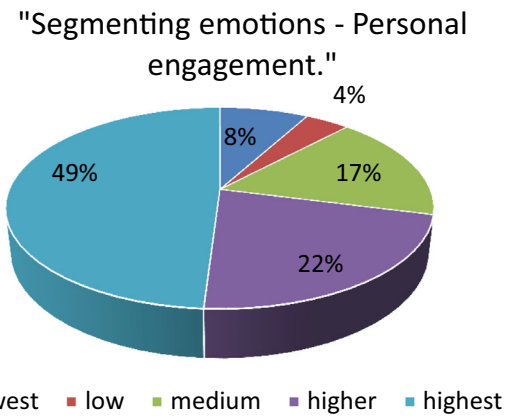

Fig. 4 Emotion segmentation—personal engagement. *Source* Own processing

5.1.1 Population Based on Emotions

The following segment was created based on the responses of our respondents. We included only those who rated the question regarding emotions and excitement with a value of five. This means that for these respondents, this item was the most important.

All the subsequent graphs show the distribution of responses from one to five, indicating the ratings given by the participant in our survey. A value of one represents the lowest importance of the respective factor for the respondent, while a value of five indicates the highest importance.

The first significant difference compared to the overall population occurs in the factor of "personal engagement" (Fig. 4). In this segment, the value of one was marked by 4% fewer respondents, and the value of two was marked by 11% fewer respondents compared to the overall population. However, it is important to note that the value of five, indicating the highest importance, was marked by the segment significantly more, with an increase of up to 19%.

Therefore, we can say that the segment focusing on emotions and excitement primarily seeks their own experience with the sport in question or the experience of those close to them. The level of significance was $p < 0.01$, indicating a strong relationship. Thus, the hypothesis regarding the relationship between factors influencing the attractiveness of sports from a marketing perspective was confirmed.

We can also conclude that if we want to leverage excitement and emotions, it is necessary to involve viewers more, so to speak, engage them in the action or somehow convey the experience to them through sports.

Another finding is that sports enthusiasts who seek emotions also have a greater demand for action and dynamism in sporting events. This is quite understandable, as it is difficult to achieve excitement without a certain level of "action" in the match (Fig. 5).

In the rating of five, there was a difference of up to 29% for this factor, placing it in the first position among all factors related to this segment. We can somewhat perceive it as an answer to the question of what attracts many people to sports. Emotions and

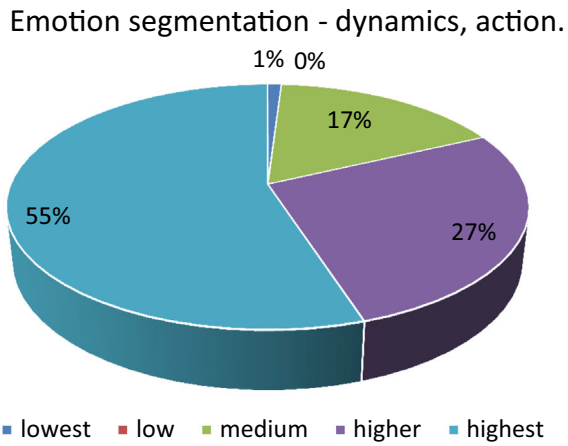

Fig. 5 Emotion segmentation—dynamics, action. *Source* Own processing

excitement, so to speak, emerge from the sport itself and appeal to a significant segment of society. And members of this segment, in 82% of cases (values four and five), demand action and dynamism.

The relationship between the factor of emotions and dynamism fluctuated at a statistically significant level of $p < 0.01$, indicating a high level of significance. We have successfully confirmed this phenomenon, which will help us better navigate the creation of sports products.

In the following graph, we observe that among individuals who identify themselves as "emotional" in the realm of sports (Fig. 6), there is a high proportion who consider technicality and tactics to be very important. This dependency between the demand for technicality and tactics and the emotional inclination of the respondents is an interesting finding. This means that if a sport does not meet the requirements for technicality and tactics, this segment of viewers will not be satisfied. It is important to note that this segment is not small, and therefore, it also has economic significance.

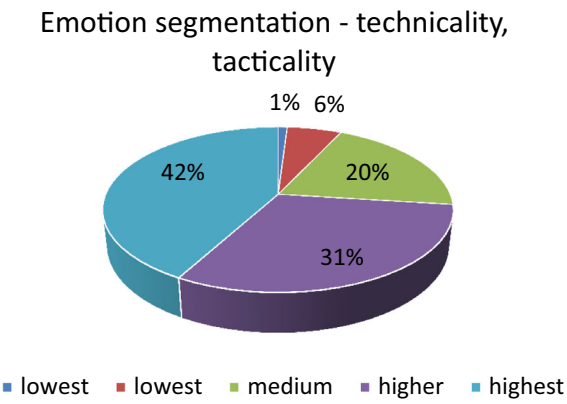

Fig. 6 Emotion segmentation—technicality, tacticality. *Source* Own processing

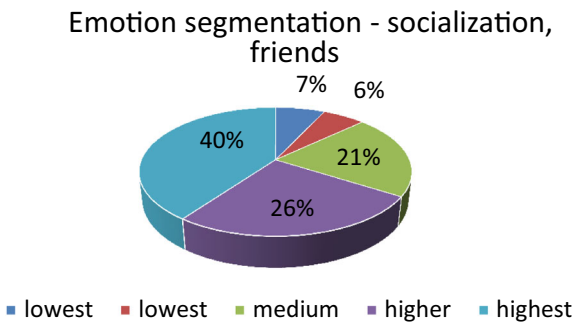

Fig. 7 Emotion segmentation—socialization, friends. *Source* Own processing

It is also important to note that in this case, a high level of dependency was found, which was confirmed by statistical significance at the level of $p < 0.01$.

The following graph illustrates how the segment focusing on excitement and emotions inclines towards the factor of "socializing with friends" (Fig. 7). In this segment, more than 20% of respondents rated it with a value of five, which is higher than the overall population. Although the frequency of a value of four was similar, these respondents marked 10% fewer values of one and two. This suggests that the segment seeking excitement has a higher need for socialization. The level of significance was again at $p < 0.01$.

Other factors that significantly influenced the frequency of occurrence in this segment were:

Difficulty of the sport: In this segment, there was a 16% increase in the number of respondents who rated it with a value of five. From this, we can conclude that people seeking excitement are interested in sports that are more challenging or are presented as demanding.

Performances: In this segment, there was a 20% increase in the number of respondents who rated performances with a value of five. This is closely related to the previous factor, as impressive and remarkable performances by athletes not only evoke admiration but also excitement and adrenaline.

Atmosphere at sports venues: Here, the frequency of a value of five increased by 17%. This proves that the atmosphere is highly important for people seeking excitement and being emotionally involved in sports events. It confirms that people don't just go to sports venues for the sport itself, but also for the specific ambiance and atmosphere, which is even more significant for this segment.

Among other important factors for this segment, whose significance did not increase as markedly, we can include the following:

- Fan atmosphere
- Uniqueness
- Regular repetition

For the last factor, the occurrence of values four and five increased by more than 16%. Although this number is not significantly different from the other factors in this segment, the importance of regular repetition of competitions for the "emotional"

segment is valuable information. While this factor is important for less than half of the people in this segment (values four, five), the shift in this direction is still relevant. It speaks to the need to maintain contact with sports fans or at least attempt a certain frequency of sports events that viewers have the opportunity to attend or watch.

The priorities of members in this segment are similar to the overall population, although health has a lower occurrence by 8%, while "friends and entertainment" increased by 7%. The importance of friends and entertainment has almost doubled in this segment, indicating that people seeking emotions and excitement are also more inclined towards friends and entertainment as life values.

We can see that members of this segment logically engage more in sports or spend time with friends during their leisure time. The group of respondents under discussion is also more active by 11%, and there is a slight shift towards extroverted individuals (9%).

Respondents in this segment are also less rational, although the occurrence of "ambitious" individuals increased by 11%.

Among the members of this segment, there are also more respondents who consider themselves to be family-oriented (the occurrence of a value of five increased by 10%), and there is a slight shift towards those who are more self-confident and identify with the culture of society.

In the following characteristics of the segment, it was found that it is younger in age, specifically with 5% more individuals in the group aged up to 17 years, and 9% more individuals in the group of 18–25 years, with a decrease in frequency of occurrence in the other age groups.

There was also a difference in the distribution of education, where there was a 6% increase in individuals with primary education, while the representation of those with higher education decreased by 9%. Within the segment of individuals strongly influenced by emotions and tension, there is a higher proportion of men. While the distribution of occupations among the various categories is similar for this segment as compared to the overall population.

6 System Integrating the Research Results

In the table below, we have compiled the key findings of our research. We aimed to include as much information as possible in one logical entity to make it as simple and useful as possible, especially for practical application. Due to the analytical nature of the research, we have elaborated on numerous insights and provided a wealth of data in the previous chapters, which we have now gathered and synthesized into a single table. The purpose of this table is to provide a useful tool for practical application.

We are confident that this table will serve as a valuable tool for professionals in the sports industry who strive to better understand the needs and preferences of their customers. The combination of multiple relevant factors in one table allows us to have a comprehensive view of the market and its individual segments. Additionally, it provides information on the changes in the importance of these factors overall and

the characteristics of each segment, which can assist in the development of targeted marketing strategies.

In the table, we have summarized the key findings of our research and divided them vertically according to the created segments. The horizontal divisions indicate the factors influencing the attractiveness of sports, supplemented with additional characteristics of each segment.

The numerical data in the table represent the percentage expression of the importance of factors for a given segment, with values four and five corresponding to the importance and maximum importance of the respective factor.

Furthermore, the table also provides information about the changes relative to the overall values. These shifts are indicated by colors, where black represents changes less than 10%, green indicates a shift of 10–14%, red in a blue cell signifies a shift of 15–19%, and finally, orange in a red cell indicates a shift above 20%.

7 Conclusion

The research we conducted in our work stemmed from the need to explore and evaluate the impact of key factors influencing the attractiveness of sports for society, specifically for potential viewers. For this purpose, we identified factors that have a significant influence and determined their weight, which represented the first part of our work. Additionally, we compiled the ranking of factors based on importance, with the first most important factor being "personal engagement" and the last factor being "duration." We also analyzed all the factors based on respondents' answers, which helped us distinguish which factors are important, which are not, and which may be supplementary or supportive.

The knowledge obtained in this way can be later utilized, especially in practical application of so-called "mass marketing," which means marketing oriented towards a broad customer base without focusing on specific market segments.

The knowledge about the weight and nature of individual factors influencing the attractiveness of sports allowed us to create seven market segments that take into account the needs of different groups of people. These segments were created based on the preferences of individual factors influencing the attractiveness of sports and include categories such as "aesthetics," "emotions," "socialization," "aggression," "national pride," "philosophical dimension," and "participation of personalities." These segments have the potential to be utilized in sports marketing to increase campaign effectiveness and precisely target those groups that are most likely to be interested in a specific sports experience.

The creation of the mentioned segments was possible mainly due to the confirmation of the hypothesis that assumed relationships between certain factors influencing the attractiveness of sports. Examples of the identified relationships include:

- The relationship between inclination towards the philosophy of sports and other aspects of sports.

- The relationship between inclination towards the philosophy of sports and enrichment of lifestyle through sports.
- The relationship between inclination towards national pride and the tradition of the event.

The research revealed numerous relationships among the mentioned factors influencing the attractiveness of sports, significantly expanding the theory of sports marketing. The new insights from the research have high potential for practical application. In sports marketing, we often encounter the audience's need for one of these factors, which can be influenced by the nature of the sports event or the viewers themselves. Through our analysis, we gained a comprehensive understanding of the needs and demands of viewers interested in a particular sport. This allows us to confidently determine what additional requirements they have for a sporting event. These findings can be utilized in the development of sports products for specific target groups. The results of our research provide a practical contribution to sports product creators, enabling them to better tailor their products to the demands and needs of the audience based on this information.

When conducting a comprehensive evaluation of factors influencing the attractiveness of sports, it is important to consider their interconnection with other population characteristics, such as sociological, psychological, and philosophical aspects. Our research confirmed the hypothesis about the existence of these relationships, providing us with even more comprehensive information.

Examples of these relationships can also include:

- The relationship between inclination towards the aesthetics of sports and emotional engagement.
- The relationship between inclination towards aggressive sports and ambition.
- The relationship between inclination towards celebrity involvement in sports and the need for power and influence.

A deeper understanding of these relationships can impact the creation and targeting of sports products towards specific groups of viewers. It can also aid in the development of a marketing strategy that is better aligned with the preferences and needs of these viewer segments.

This means that these segments are not only relevant for understanding the factors influencing the attractiveness of sports but are also valuable for planning and implementing marketing activities. Knowledge of the preferences and needs of sports viewers allows us to better target our communication, thereby increasing the effectiveness of our marketing investments and improving the return on marketing investment.

Our goal was not only to acquire data but also to ensure their practical usefulness. There is a risk that a vast amount of data will remain unused if not presented in a concise, clear, and comprehensible form. Therefore, we created a synthesizing element in the form of a table that integrates the maximum amount of data into one coherent and understandable entity. This table provides an overview of the obtained information and relationships and has the potential to serve as a tool for practical

sports marketing. It represents the culmination of our work and ensures that the acquired insights will be valuable and practically applicable.

Based on the fulfillment of all defined objectives and confirmation of all hypotheses, we can state that our research represents a contribution to the field of sports marketing theory. We believe that its practical impact will be visible and will serve as a tool for increasing the attractiveness of sports. We hope that our findings will find recipients and that their application will bring specific benefits to all stakeholders involved.

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Predictive Risk Management in the Supply Chain

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Abstract This article, a systematic literature review on 'Predictive Risk Management in the Supply Chain', presents significant findings. It analyses the current state of research and identifies trends, challenges, and solutions. The analysis is based on 13 scientific articles from 2021 to 2024. The results underscore the increasing use of technologies such as artificial intelligence (AI), machine learning (ML), and big data analytics (BDA) for risk prediction and management in supply chains. These innovative approaches enable early risk identification, process optimisation, and informed decision-making, offering a promising supply chain risk management future. The main challenges identified are the complexity of supply chains, the subjectivity of human risk assessments, and the implementation of new technologies and data analytics. The studies propose various solutions, such as integrating AI and ML into risk management, using BDA for improved transparency and predictions, and developing technology-enabled risk assessment methodologies. The research highlights the potential of modern technologies for more efficient, agile, and resilient supply chain risk management (SCRM), instilling a sense of optimism in the audience.

Keywords Supply chain · Risk management · Predictive

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1 Introduction

The Asian board game Go is 3000 years old and has a high number of recorded play possibilities, so for a long time, it was considered impossible to predict individual moves even by artificial intelligence (AI). As a result, average-good Go players regularly won against above-average artificial intelligence until analysts developed the idea of programming AlphaGo with 30 million smartest moves in humans. This made AlphaGo so good that the program won four to one against the then-reigning world champion, Lee Sedol. This led to whether the programming data was based on the best moves. The idea arose to let two artificial intelligences (AlphaGo Zero), just knowing the Go rules, play against each other 29 million times and learn from each other. AlphaGo Zero and AlphaGo then competed against each other. AlphaGo Zero, without human experience data, won 100 to 0 against AlphaGo. This not only leads to the conclusion that humans have been playing Go for 3000 years without really understanding the principle of the game but that surprising insights can also lurk in value-added processes. To this end, the practical recommendations for theory, practice and future research in predictive SCRM are a source of inspiration and motivation. Predictive SCRM, crucial in today's global markets, involves using advanced analytics and technologies like AI and ML to analyse data, identify patterns, and predict disruptions, enabling proactive risk mitigation. Managing supply chain risks is a critical strategic issue for companies with increasing complexity and volatility in global markets. To ensure a robust and stable supply chain, potential risks must not only be identified and understood, but they also have to be predicted. In this context, predictive risk management in the supply chain is becoming the focus of current research and practical applications. This paper aims to comprehensively analyse the current state of research and practice in predictive SCRM, which holds significant value in providing insights into the latest developments, challenges and opportunities. Therefore, this article aims to answer the following questions: What are the current topics of predictive SCRM, and what would the future be like in predictive risk management in the supply chain? To answer these questions, this article will be divided into several main sections to ensure a thorough examination of the topic. The following chapter overviews the existing theoretical framework and the current application of predictive risk management strategies in the supply chain. Afterwards, the methodological approaches for implementing this systematic literature review are presented. This is followed by a summary of the key findings from the literature review, including the trends, technologies and strategies identified. Based on the research results, these practical recommendations aim to engage readers and stimulate their interest in applying the research findings to their own work. The novelty and relevance of the research will surely pique the curiosity of academic researchers and professionals. The thoroughness of the literature review process, which ensures a comprehensive understanding of the topic, should give the audience confidence in the research findings and recommendations.

2 Current State of Dealt Problems

Supply chains are exposed to various risks in an increasingly globalised and complex world. Natural disasters, political instability, cyber-attacks and sudden fluctuations in demand can severely disrupt the supply chain and cause significant costs. Therefore, effective predictive SCRM is essential to ensure business resilience and continuity. Predictive risk management in the supply chain aims to identify and assess potential risks early and take appropriate risk mitigation measures before disruptions occur. Nakano [1] this includes identifying and assessing risks, monitoring and early warning systems, building resilience and redundancies, and collaboration and transparency along the supply chain. Nakano [1] resilient supply chains optimise production through planning, understanding, and using data. Nakano [2] through this proactive approach, companies can minimise the impact of disruptions and maintain their competitiveness. Reactive risk management, on the other hand, which only reacts after an event occurs, can lead to significant costs, reputational damage and loss of market share. Strategic supply chain planning synchronises all components and provides greater visibility and flexibility to anticipate problems better and limit the impact of disruptions. Werner [3] to mitigate risk, it is important to define a comprehensive SCRM policy that answers questions about information collection, monitoring, assessment, contingency plans and communication. Nakano [4] technologies such as machine learning can support risk identification by using millions of data to make similar predictions and derive recommendations for action, like AlphaGo Zero [5].

3 Methods

This study aims to investigate the role of predictive risk in the supply chain, an area of particular importance given the increasing volatility of global markets. A systematic literature review was conducted to gain an in-depth understanding of the current research landscape and related developments. This was based on carefully selecting search parameters to identify the most relevant and up-to-date articles.

The search parameters for this study were defined as follows: The search term "supply chain AND predictive risk" was used in the title and the abstract to ensure that the articles found addressed aspects of predictive SCRM. The search was limited to articles in English to ensure the standardisation of the search results. Only review articles were selected as document types, providing a comprehensive overview of existing research and theories and representing a solid basis for the analysis. The time frame of the search ranged from 01 January 2021 to 25 March 2024, ensuring the data's relevance and timeliness.

The search was conducted without limiting the area of research to include a broad range of disciplines and perspectives. This systematic search was conducted in two leading academic databases: Web of Science and EBSCOhost. The Web of Science

database yielded nine hits, while the EBSCOhost database returned 146 articles. After carefully checking for duplicate search results and reviewing all the document abstracts, three articles from Web of Science and ten articles from EBSCOhost were identified as particularly relevant and selected for further analysis. The selection processes in both databases were characterised by thoroughly examining and evaluating each article based on the defined criteria. This approach ensures that the articles used for this study provide an accurate picture of current research in predictive risk in the supply chain. The selected articles provide a multi-layered perspective on the topic, encompassing quantitative and qualitative research methods, thus contributing to a comprehensive understanding of the topic under investigation.

This table lists the found studies, including the authors, the year of publication, the study title, the given keywords, and a description of the chosen methodology. It offers a range of methods, including literature reviews, quantitative validation of data from supply chain operations, and qualitative methods (Table 1).

MAXQDA was used to search the text of the documents for the most frequently occurring words (word cloud), the number of documents in which each word was found and the percentage of these documents about the total number of documents. The terms “supply”, “chain”, “risk”, and “management” were excluded from the word cloud because they were too general, and the intention was to use current terms/trends from current literature. The results of the word cloud are summarised in Table 2.

The following illustration shows the frequency of keywords that the authors have assigned to their documents (Table 3).

4 Results

This section lists the different documents and reduces them to their core statements to create a synthesis. This is important for recognising trends, correlations, or even mutual exclusions.

Emmanuel et al. analysed the correlation between drug SCRM and the use of predictive parameters in research on the spread of disease, particularly using ML methods over the last five years. They used 71 articles that met the criteria for inclusion and exclusion and systematic review methodology. The study categorises the results into three broad groups of disease outbreaks. It used ML algorithms to predict the spread of these outbreaks. The paper found that using parameters for ML predictions correlates with managing drug supply in the case of coronavirus disease. The authors also found that the main issues lie in the production and demand gaps, ambiguity and uncertainty from the user side, as well as the challenge of accurately predicting drug demand. These challenges are further intensified by the dynamic nature of disease characteristics and rapid changes in patient care. The study emphasises that the accuracy of epidemic case predictions is critical for determining intervention, control strategies and integrated decision-making. It also suggests using

Table 1 Synopsis of the filtered literature (own representation)

No.	Author	Year	Title	Keywords	Research methodology
1	Emmanuel et al	2023	Machine learning in drug supply chain management during disease outbreaks a systematic review	Disease outbreaks; Drug supply chain; Endemic; Machine learning; Prediction;	Literature review
2	Deiva Ganesh and Kalpana	2022	Future of artificial intelligence and its influence on supply chain risk management—A systematic review	Artificial intelligence; Risk management; Machine learning; Proactive decision-making;	Literature review
3	Du et al	2022	Monitoring corporate credit risk with multiple data	Corporate Credit Risk; Prediction; Multiple Data Sources; Machine Learning; Support Vector Machine;	Literature review & and qualitative method (Delphi)
4	Wolniak and Grebski	2023	The applications of usage of business analytics in Industry 4.0	Business Analytics; Industry 4.0; Digitalization; Artificial Intelligence; Real- Time Monitoring;	Literature review
5	Burstein and Zuckerman	2023	Deconstructing Risk Factors for Predicting Risk Assessment in Supply Chains Using Machine Learning	Supply Chain; Risk Management; Operational Risk;	Validation using Data
6	Liu	2021	Risk Prediction of Digital Transformation of Manufacturing Supply Chain Based on Principal Component Analysis and Backpropagate	Digital transformation; Manufacturing Supply Chain; Risk Factor; Backpropagation Neural Network; Principal Component Analysis;	Validation using Data
7	Petriashvili and Khomeriki	2024	The Impact of Artificial Intelligence in the Business Process in the Phase of Data Analytics	IoT; SCM; Blockchain;	Validation using Data
8	Ali et al	2021	Fusion-Based Supply Chain Collaboration Using Machine Learning Techniques	Business intelligence; k-nearest neighbour; Machine Learning; Simulation; Supply Chain Collaboration; Support Vector Machine	Validation using Data

(continued)

Table 1 (continued)

No.	Author	Year	Title	Keywords	Research methodology
9	Brintrup et al	2023	Digital supply chain surveillance using artificial intelligence definitions opportunities and risks	Artificial Intelligence; Machine Learning; Supply Chain Surveillance; Digitalisation; Explainability; trustworthy AI;	Validation using Data
10	Rezki and Mansouri	2023	Improving supply chain risk assessment with artificial neural network	Supply Chain Risk Management; Artificial Neural Network; Risk Prediction; Risk Assessment; supply chain;	Validation using Data
11	Aljohani	2023	Predictive Analytics and Machine Learning for Real-Time Supply Chain Risk Mitigation and Agility	Machine Learning; Predictive Analytics; Real-Time Monitoring; Supply Chain Agility; Supply Chain Risk Management;	Validation using Data
12	Agarwal et al	2023	The role of smart technologies in managing supply chain post-pandemic: an exploratory scientific procedures and rationales	Supply Chain Management; SPAR-4-SLR; Bibliometric Analysis; Industry 5.0; Smart Technologies	Literature review
13	Assis Santos	2022	Big data analytics for supply chain risk management: research opportunities at process crossroads	Big Data Analytics; Supply Chain Risk Management; Startups; Literature Review	Literature review

Table 2 Results of the word cloud (own representation)

Rank	Word	Frequency	Found in documents
1	Process	461	13
2	Machine	388	12
3	Information	372	13
4	Technology	369	13
5	Supplier	348	13
6	Analytics	338	12
7	System	328	13
8	Network	314	12
9	Company	311	12
10	Prediction	304	11

Table 3 Frequency of keyword (own representation)

Rank	Word	Frequency	Found in documents
1	Machine	8	6
2	Learn	6	6
3	Artificial	4	4
4	Intelligence	4	4
5	Analytics	3	3
6	Prediction	3	3

technology to predict drug demand and optimise SCRM processes, particularly ML [6].

These and other predictive models enable extracting patterns and knowledge from large amounts of data. This can be used to make more informed decisions about the production and distribution of medicines. The development of ML technology in predicting market demand makes it possible to forecast the spread of disease outbreaks. External variables such as drug distribution and availability in the pharmaceutical units must also be considered. The authors provide valuable insights into the complexity and challenges of managing drug supply chains during disease outbreaks and the potential role of machine learning as a tool to improve predictive accuracy and efficiency in this area. The need for interdisciplinary approaches that combine technology, pharmacy and health sciences to strengthen the resilience of pharmaceutical supply chains in times of crisis becomes abundantly clear.

By analysing the existing literature from 2010 to 2021, Deiva Ganesh et al. have identified unexplored and missing aspects in current research, challenges in implementing AI technologies in SCRM, and promising directions for future research. The authors introduce the paper by stating that despite extensive research in SCRM, industries still face significant challenges in managing supply chain risks. These challenges have been compounded by global pandemics and the increase in unpredictable events such as natural disasters, fluctuations in demand and political changes. The need for data-driven, proactive and predictive risk management mechanics that rely on AI and ML is emphasised to improve accuracy in predicting uncertainties. This understanding is critical to fostering a willingness to address existing challenges and develop a robust and resilient supply chain. A major barrier would be the lack of AI and ML integration in SCRM, which is still early. The authors emphasise an urgent need for systematic research to exploit the full potential of AI for SCRM. As a solution, a conceptual framework is proposed to achieve a comprehensive risk management process that includes identifying, assessing, mitigating and monitoring risks in the supply chain [7].

The study highlights various AI and ML methods that can be applied in the different phases of SCRM and emphasises the importance of integrating these techniques to improve resilience, agility and predictability in the supply chain. AI and ML have the potential to transform SCRM by enabling more accurate predictions and decisions, contributing to the development of robust and resilient supply chains.

The article by Du et al. uses multiple data sources to discuss the challenges and solutions in corporate credit risk (CCR) assessment. The main problem described in the article is that traditional CCR monitoring relies mainly on financial indicators such as income, debt and inventory at the company level. These are usually published by the target companies on a quarterly or annual basis. The traditional models often do not consider the existing and significant information from different sources or channels, such as data from partner companies in the supply chain or publicly available network data. However, these could help to reveal a change in the CCR and thus indicate an increased risk along the supply chain [8].

By incorporating this data, the study seeks to assess the impact of supply chain and network activity data on the prediction of CCR. Machine learning is used to improve prediction accuracy, utilising the Support Vector Machine (SVM) algorithm to process non-linear data sets and identify complex relationships between multi-variable indicators for CCR assessment. The results show that after adding supply chain and network activity data, the predictive errors of the datasets could be reduced to the lowest level ever. Intelligent algorithms such as SVM led to a significant improvement in predictive precision compared to traditional methods. According to the authors, the study suggests integrating multiple information sources in combination with intelligent algorithms can help companies prevent risk overflows and enable a more informed evaluation of credibility (for both organisations and customers).

In the era of Industry 4.0, which is characterised by the networking of machines, products and systems, companies face the challenge of using the flood of available data to optimise their operating processes. Business analytics in this context aims to gain valuable insights from the vast amounts of data, which can increase efficiency, reduce costs and improve competitiveness. According to Wolniak and Grebski, the main challenge lies in effectively using and analysing data from various sources such as sensors, IoT devices and production equipment. Organisations have to be able to collect, integrate and analyse this data to gain insights into their operations and make informed decisions. In doing so, they must be able to cope with the complexity and volume of data generated by the digitalised processes of Industry 4.0. Wolniak and Grebski see business analytics as the key to solving these challenges. Analytical methods allow companies to make precise predictions, optimise processes and make strategic decisions based on sound data [9].

This understanding encourages the willingness to invest in appropriate technologies and skills to fully utilise the potential of business analytics. It is recognised that the effective use of business analytics enables companies to improve their operations continuously, minimise risks and stay one step ahead in the fast-moving business world. The authors are of the view that there are solutions to the problem identified. First, predictive maintenance enables companies to predict potential equipment failures and carry out preventative maintenance to minimise downtime and extend the life of equipment. Maintenance needs can be accurately predicted and planned by analysing historical and real-time data, resulting in significant cost savings. Second, supply chain optimisation: By using business analytics, companies can improve resource allocation, reduce costs and optimise customer service through data-driven

decision-making. This includes a demand forecast, inventory management, logistics planning, and supplier performance evaluation. Third, quality assurance also benefits significantly from the use of business analytics. Companies can quickly identify and correct product defects by continuously monitoring production processes and quality parameters in real-time, increasing product quality and customer satisfaction and reducing costs.

The study by Burstein and Zuckerman aims to minimise human subjectivity in supply chain risk assessment and achieve the most objective risk assessment possible through ML. According to the authors, the main problem in SCRM lies in the subjectivity of auditors when determining risk levels. Different auditors can have different opinions in the same situation. This is due to their individual experiences and histories. Given the increasing complexity and frequency of risk events, this can become problematic, undermining the consistency and reliability of risk assessments. In addition, the increased complexity of supply chain relationships and various disruptions such as climate change, COVID-19 and geopolitical scenarios have increased the importance of effective risk management along supply chains [10].

The study recognises that current approaches to risk management, often reactive and based on historical data, are insufficient to meet the challenges in a dynamic and uncertain environment. It emphasises the need to move from a reactive to a proactive risk management approach that uses predictive analytics and ML to identify and mitigate risks in advance. The aim is to develop a more objective and less subjective assessment system that minimises human bias and enables a more reliable risk assessment.

Liu has produced a study that uses Principal Component Analysis (PCA—one of the most popular methods for dimensionality reduction) and Backpropagation Artificial Neural Network (BPNN) to predict the risk of digital transformation of the manufacturing supply chain (MSC). It provides a detailed examination of the challenges associated with digitalising supply chains in the manufacturing industry and innovative solutions to overcome them. The author describes how the digitalisation of the manufacturing supply chain is associated with a wide range of uncertainties which result from the dynamics and complexity of its nodes and structures. These uncertainties are further increased by increasing customer requirements and intense market competition. The main problem would be that digitalisation can potentially improve supply chain efficiency and responsiveness. It also would introduce new risks that can threaten successful supply chain management. These risks include data privacy issues, technology integration difficulties and the risk of information bias. To effectively support the digital transformation needs of MSCs, the study emphasises the need to develop a comprehensive understanding of identifying and predicting risk factors. This includes creating an assessment index system for MSC digital transformation based on identifying risk sources. By applying PCA to reduce the dimensions of the original data, it is possible to select the characteristic parameters for risk prediction more effectively. This helps reduce the problem's complexity and provides a solid basis for creating the solutions. The core solution of the study is the development of a BPNN model based on the data reduced by PCA to predict the risks in the digital transformation of the MSC. The BPNN model uses the selected

principal components as input to predict the risks accurately. The study shows that the BPNN model achieves a good prediction performance and is performing better than traditional neural network models [11].

Using BPNN, companies can identify potential risks in prior and develop relevant risk mitigation strategies. This can lead to a smoother and more successful supply chain digital transformation. In conclusion, the study emphasises the importance of risk prediction and management in the digital transformation of the manufacturing supply chain. The innovative combination of PCA and BPNN provides a new approach to addressing the challenges associated with supply chain digitalisation. According to the author, the findings of this research provide valuable insights for executives and decision-makers in the manufacturing industry by demonstrating how data-based risk prediction models can support the planning and implementation of digital transformation strategies.

The study by Petriashvili and Khomeriki focuses on the role of AI and data analytics, particularly in SCRM. The authors highlight how integrating advanced technologies is transforming traditional supply chain practices. According to the authors, this increases efficiency, improves transparency, and enables more accurate decision-making. The study finds that SCRM is a complex, dynamically changing system influenced by multiple factors. These factors include investment policy, scientific and technological development, supplier and customer density, geographic location, demand dynamics, competitive conditions, etc. This complexity makes it difficult for managers to achieve high optimisation and rationalisation in the supply chain. The supply chain is a fully integrated, customer-centric system critical to planning, creating, administrating, and managing material flows and determining the optimal value-added factor. Focusing on the significant role of data analytics and digitalisation creates challenges in SCRM. The authors explore how data analytics is critical in real-time visibility, predictive analytics for demand forecasting, and effective risk management. They also highlight the importance of digitalisation by introducing technologies such as the Internet of Things (IoT), blockchain, and automation. These technologies offer new opportunities for supply chain optimisation through improved tracking capabilities and overall efficiency. According to the authors, integrating IoT devices and smart sensors increases transparency and accountability by providing real-time data on goods' condition, location and status. Blockchain technology, on the other hand, contributes to traceability and transparency, reducing the risk of fraud while optimising supply chain efficiency. Automation and robotics optimise supply chain processes, increasing efficiency, lowering operating costs, and facilitating faster order fulfilment [12].

There is a focus on utilising data for sustainable practices to assess and improve the environmental impact of supply chain activities. The study concludes by recognising that AI and data analytics play a revolutionary role in SCRM by improving process efficiency, decision-making, and risk management. Companies must adapt to these technological advances to effectively take advantage of the challenges and opportunities in the ever-changing business world.

Ali et al. focus on the challenges and solutions in the Supply Chain Collaboration (SCC), specifically with machine learning. The authors identify the main

problem of SCC as being the complexity in a dynamic and often unpredictable business environment. It is emphasised that the success of supply chain organisations depends on integration, teamwork and information communication. The challenge lies in balancing competing priorities such as process robustness, risk minimisation, vulnerability reduction, real financial risks and resilience against just-in-time and cost efficiency. The document identifies that decision-making has to be driven by shared information to ensure supply chain performance and competitiveness. To overcome the challenges described, machine learning within simulation and modelling techniques is proposed as a solution. The limitations of classical data fusion methods can be overcome using fusion-based machine learning. This requires more computing power and predictive capability. A specific model is presented for SCC that aims to increase efficiency through improved decision-making. The suggested solution model utilises two specific machine learning algorithms: K-Nearest Neighbour (k-NN) and Support Vector Machine (SVM). Integrating them into the cloud improves SCC and optimises the entire process through ML. This model was simulated and analysed on a cloud platform to demonstrate its functionality and applicability in the real world [13].

The paper addressed the need to use modern technologies, particularly ML, to address SCC challenges and improve decision-making. The goal of creating an intelligent architecture for SCC was achieved by developing fused machine-learning methods.

Brintrup et al. use AI to analyse digital supply chain surveillance (DSCS). Here are the key points: The main problem documented is the challenge of monitoring and analysing supply chain information without the explicit consent of the companies involved. In today's dynamic business world, characterised by complex supply networks, AI increases the ability to monitor on a large scale, providing opportunities to identify risks, unethical practices and environmental impacts. At the same time, this results in many risks, such as faulty or biased AI algorithms that can lead to incorrect conclusions. The article proposes utilising the possibilities of AI in DSCS to improve transparency, sustainability and resilience in supply networks. Various machine learning techniques and predictive algorithms are considered to recognise critical actors and dependencies automatically. A focus is also placed on the importance of explainability, even if practitioners often favour accuracy. The study presents various AI-powered methods for monitoring and analysing supply chains, including case studies, which demonstrate the application and effectiveness of these approaches in practice. Despite users' preference for accuracy over explainability, the article highlights concerns, such as bias and misinterpretation by AI, which can lead to sub-optimal decisions [14].

To address these challenges, illustrative cases highlight potential risks and suggest key areas for further research. The balance between AI's tremendous opportunities for supply chain monitoring and the associated risks must be carefully managed to promote sustainable and ethical supply chain practices.

The study by Rezki and Mansouri also presents a methodology that uses artificial neural networks (ANNs) for risk assessment in supply chains to minimise the subjectivity of human assessments and achieve a more objective assessment of risks.

According to the authors, the main problem in SCRM is the subjectivity of human judgment. These are influenced by individual experience, expertise and personal prejudices. This subjectivity can lead to inconsistent risk assessments, which can undermine the effectiveness of risk management. In addition, the complexity of production processes, unpredictable fluctuations in demand and various types of disruption increase the risk of significant losses. The authors recognise the need to move from a reactive to a proactive approach to risk management. This requires predictive analytics and machine learning to identify and mitigate risks in advance. The study aims to develop a more objective and data-driven assessment system that reduces human bias and enables a more reliable risk assessment. The authors propose an innovative methodology that deconstructs risk factors into sub-factors and utilises an ANN model as a predictive tool for accurate risk predictions. Real-world data from a global automotive company specialising in wire harnesses was used to train the neural network model. The model performed well in risk prediction [15].

This research contributes to the advancement of risk management practices by addressing the challenges of subjectivity in human judgement and providing a reliable and data-driven framework. This is intended to assist managers in strategic decision-making and strengthen supply chain operations through an early risk alert system. The study provides a significant advance in SCRM science by demonstrating how AI, specifically ANNs, can improve accuracy and objectivity in risk assessment. This enables organisations to proactively manage risk and increase the effectiveness of their risk management process.

Aljohani focuses his study on using predictive analytics ML to improve real-time agility and risk mitigation within supply chains. The research highlights the need to move from reactive to proactive risk management strategies in an environment with increasing uncertainty and rapid change. The main contribution of this study lies in developing and validating a framework that integrates predictive analytics and ML into SCRM. This enables organisations to identify potential disruptions and risks in real-time and act proactively (instead of only reacting to events that have already occurred). So, predictive analytics and ML are used to predict and mitigate risks. This must allow organisations to react faster and more effectively to unforeseen changes and disruptions. This is a key component of competitiveness in today's business. The study further enhances the understanding of risk management strategies by analysing the potential applications of predictive analytics and ML in SCRM. It provides an in-depth insight into the benefits of these technologies for risk prediction and mitigation [16].

This article demonstrates a practical implementation and case studies from different industries. These case studies illustrate how the proposed methodology can be applied in the real world. It encourages broadening the application areas of AI technologies in risk management and exploring the effectiveness of different predictive models and algorithms in different supply chain contexts.

The study by Agarwal et al. takes an in-depth look at how smart technologies (ST) have significantly changed SCRM in the wake of the COVID-19 pandemic. The pandemic has left a deep mark on global supply chains, requiring a rethink in resilience and adaptability approaches. A systematic literature review analysed ST's

contributions and potential in the SCRM context. The authors describe how global lockdowns and travel restrictions have led to significant delays in production and distribution during the pandemic. These exposed weaknesses in supply chains and forced the companies to rethink their dependencies and risk management strategies. These sudden and unexpected disruptions highlighted the need to make supply chains more resilient and flexible. The study discusses how ST can help strengthen the resilience of supply chains. The authors argue that technologies such as the IoT, AI, blockchain and data analytics are essential for gaining real-time insights into supply chains, optimising processes and making decisions based on big data. The study identifies key technologies and their application in SCRM. The study also emphasises that integrating ST into SCM improves resilience to future disruptions and contributes to companies' sustainability and ecological awareness. The authors conclude that the digital transformation of supply chains requires continuous effort and a willingness to adopt technology and develop new skills [17].

According to the authors, the study's findings offer valuable pointers for companies looking to redesign their supply chains post-pandemic. The study's findings also highlight the importance of ST for more efficient, transparent, and resilient supply chains.

Assis Santos and Marques focus on using BDA in SCRM. Despite BDA's enormous potential to improve SCRM processes, there is a significant research gap in applying these technologies for risk minimisation, monitoring, and optimisation in supply chains. The paper outlines how BDA can improve visibility within the supply chain and provide decision-makers with accurate, predictive and prescriptive analytical tools. These tools should help to identify risks better, assess them, and take action to mitigate them. In particular, the study highlights the importance of prescriptive BDA approaches based on multi-tier and multi-directional solutions to support risk response and optimisation [18].

The article shows that despite the recognisable benefits of BDA in risk management research, only a few studies deal with advanced BDA techniques in SCRM. It emphasises that risk response, planning, and optimisation, in particular, offer significant research opportunities using BDA. The analysis of existing literature and interviews with BDA start-ups showed a clear gap between current research and the opportunities offered by innovative technologies.

5 Discussion and Conclusion

The discussion around predictive risk management in the supply chain opens up various perspectives and recommendations for theoretical research and practical application. These recommendations outline how academics and practitioners can address the challenges and opportunities of progressive new technologies. The theory behind predictive risk management and the use of technologies such as AI, ML, and BDA in the supply chain are at an exciting inflexion point. It is becoming clear that deeper and broader research in these areas is desirable and necessary to push

the boundaries of current understanding. Particular attention should be paid to the decision-making processes: How do decision-makers adopt the recommendations that result from digital technologies? What will the future role of human decision-makers be? What psychological and organisational barriers stand in the way of effective use? In addition, developing and refining theoretical models that enable the seamless integration and utilisation of digital technologies in supply chains is crucial. Understanding and modelling the dynamics between human decision-makers and machine systems is particularly important. The discussion around predictive risk management in the supply chain opens up various perspectives and recommendations for theoretical research and practical application. These recommendations outline how academics and practitioners can address the challenges and opportunities of progressive new technologies. Advanced analytics and automation open up new opportunities for practitioners in the field of supply chain management. However, these also have their challenges. Integrating AI and ML into existing supply chain management systems is a key recommendation. However, this requires technological adaptations and a rethink among employees and managers. Training programmes that promote the understanding and applying these new technologies are essential. At the same time, organisations must learn to adapt quickly to technological changes and cultivate a continuous improvement and innovation culture. Only in this way can they fully realise the advantages of digital transformation and minimise risk simultaneously. It will be an exciting time for everyone involved as the boundaries of what is possible are constantly being pushed.

This research documentation also provides a comprehensive insight into the current topics of predictive SCRM. The future of predictive risk management in the supply chain is presented by carefully analysing various studies. Once the individual articles had been viewed and evaluated, the individual proposed solutions could be categorised. These were categorised as "Technological solutions" and "Non-technological solutions", as shown in the following overview. All the articles suggest technological approaches for predicting risks in the supply chain. The theoretical analysis of the research highlights how AI, ML and other digital innovations serve as critical tools for improving the efficiency and flexibility of supply chains. These technologies enable companies to analyse data in real-time, automate processes and make informed decisions. Especially in crisis times, these technologies can help. They can make supply chains more resilient and minimise supply disruptions. The theoretical findings also show the need for a predictive method that makes it possible to identify potential risks and disruptions in advance and take the necessary steps to counter them. Integrating digital innovations into risk assessments makes it possible to create more accurate forecasts. That will enable proactive risk mitigation and efficient resource allocation. In practical terms, the research emphasises the importance of implementing these technologies in the operational aspects of supply chain management. The use of AI and ML will not only improve the prediction and management of risks but will also increase the supply chain's agility, resilience and efficiency. Practitioners are encouraged to adopt these technologies to gain real-time insights, optimise processes and make informed decisions, thereby

mitigating risk and improving supply chain performance. However, the implementation of these technologies requires not only a technological upgrade. It will also have a cultural and organisational adjustment within the companies. Only an environment that encourages innovation and development can use this technology. Digitalisation will also require coordinated organisations, which means new organisational challenges. The research demonstrates that the future of supply chain management heavily depends on integrating and applying advanced technologies. The research findings provide a framework for a deeper understanding of the potential of AI, MI and BDA. The practical conclusions provide a clear but not straightforward guide for implementing these technologies into daily operations. Companies willing to invest in these technologies and foster a culture of continuous improvement and innovation will be better positioned to effectively manage risk and achieve sustainable success in the globally connected economy.

6 Limitation

The study is based on a limited number of recent research papers. The findings and conclusions result from a systematic literature review and have not been validated by empirical data or practical applications. Another potential limitation is that while the study emphasises the importance of integrating AI, ML and BDA into SCRM, it does not provide detailed guidance or frameworks for implementing these technologies in companies. The practical challenges and barriers to implementing such advanced technologies require further research. Future studies should focus on the technological aspects of predictive risk management in the supply chain and include the crucial organisational, cultural and human factors for successful implementation.

7 Annexes

Attached are two digitised documents.

The data corpus contains the following contents:

- Main challenges which each paper of the systematic literature review has found (Annex 1)
- Suggested solutions for each article by the systematic literature review (Annex 2)

The annexes are available at the following link:
https://osf.io/d7w8g/
The appendix can also be accessed via the following DOI:

8 https://doi.org/10.17605/osf.Io/d7w8g

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Employer Branding and Talent Management

Matthias Bender and Lubica Bajzikova

Abstract Due to the current framework conditions, the labor market has become an employee market. This means that companies can no longer choose their future employees. Instead, they must assert themselves against other companies to win over the available applicants. To achieve this goal, applicants must be made aware of the company in an appropriate manner and be enthusiastic about the company. Employer image and talent management play a key role in this. The German brewing industry has many older employees who will gradually leave the labor market over the next few years. Career sites on the Internet are a cost-effective tool in the battle for young talent. The following article examines how large and how detailed the Internet presence of German breweries is. It was found that most of the breweries selected here have a high-quality online presence. However, the focus is currently still on the product and less on the staff.

Keywords Employer branding · Talent management · HR marketing · Corporate image · Online presence · Regional focus

1 Introduction

"*Do good things and talk about it*" (Georg Volkmar Graf Zedtwitz-Arnim, translated)

The implementation of personnel management tasks in companies has a long history behind it. This began with the Welfare Movement during industrialization in England, through Taylor's Scientific Management, the Behavioral Approach and Personnel Management and finally HR Management [1]. The aim was and is to make efficient use of the workforce. Due to various trends like the demographic change

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and the availability of the internet [2], companies now must fight for their employees. Against this backdrop, the German brewing industry is particularly interesting, as 40% of employees were aged between 50 and 64 in 2016 [3]. Since the Internet is one way of obtaining information, this article will examine the current use of the Internet for the purpose of recruiting personnel in the German brewing industry.

1.1 Relevance

If one follows the business press closely, one notices that the topic of staff replacement is repeatedly addressed by various authors. Banze et al. point out that only 8.4 million members of Generation Z will be available in Germany by 2036 to replace the 12.9 million older workers who are gradually leaving the labor market [4]. Kugel points out that in 2023 there was not only a shortage of skilled workers, but also of unskilled workers [5]. This also explains why only 2% of Germans currently state that unemployment is one of their biggest concerns [6].

This development comes as no surprise. The challenge of demographic change has long been pointed out [2, 7]. Although Chambers et al. did not refer to demographic change, they pointed out as early as 1998 that the potential of particularly high-performing employees would decrease in the coming years. Talent management was proposed as a solution to this challenge back then. In addition, companies should develop an "*employee value proposition"* [8].

Li states that "*the competition among enterprises in the twenty-first century is the competition of human resources*" [9]. However, more recent studies also show that the shortage of skilled workers is a major problem [10, 11].

Remarks: Several questions arise from the introduction. Firstly, the question emerges as to whether all companies are equally affected by this challenge, or whether there are differences? Which channels are used to pass on information? What information is shared? Is it only about the presentation of the product, or is an employer brand also presented? How are the corporate brand and talent management connected? And can conclusions be drawn from the Internet about how employees are treated within the company? From these general questions the following three research questions were derived:

(1) Which company characteristics influence the implementation of cross-sectional topics such as talent management and employer brand?
(2) How is the employer brand presented on the websites of German breweries?
(3) How do the websites of German breweries present their talent management?

1.2 Goals and Objectives

The main goal was to determine which HR information is made available on the Internet by German breweries. To achieve this main goal, the following objectives are to be worked on:

(1) Identification of characteristics that can complicate the implementation of cross-cutting issues such as employer branding and talent management in a company.
(2) Identification of the employer branding characteristics on the respective website.
(3) Identification of talent management characteristics on the respective website.

Sub-objectives 1 is to be achieved by conducting an exploratory review [12] and sub-objectives 2 and 3 by carrying out a qualitative content analysis [13].

2 Theoretical Background

The theoretical background was compiled based on an exploratory review [12]. The topics of talent management, employer branding, brand, HR marketing and small and medium-sized enterprises (SME) were examined.

2.1 Talent Management

A definition of talent management translated from German is as follows: Talent management "*refers to internally and externally directed strategies, methods, and measures with which a company ensures that the key positions critical to business success are filled with the right employees: the goal-oriented action to discover, attract, develop, promote, optimally insert and retain talent*" [14]. The latter actions—discover, attract, develop, promote, insert and retain—are core elements (tasks) that can be found in various versions [15–21]. However, some authors add further aspects to these core elements. Trost adds a competency model [19]. Ritz, et al. classify the core elements in an overall concept and explicitly state how important the holistic implementation of the process is [15]. Kahl already pointed out in her comments in 2011 that many employers will have to apply to employees due to the framework conditions and that a strong employer brand is therefore necessary. And the employer brand is developed through employer branding [16].

Before the talent management process can be implemented, the employer must determine how this process should be fundamentally aligned. There are two approaches to choose from: the inclusive and the exclusive approach. If all employees in a company are seen as talent, an inclusive approach is implemented. If only part of the workforce is perceived as talent, the exclusive approach is used [18].

In his comments on talent management, Trost distinguishes between medium-sized and large companies. He refers to two myths that are present in medium-sized

companies in this context. Myth number 1 states that talent management is not necessary for medium-sized companies, as filling key positions is automatic due to their size. Myth number 2 states that talent management can be implemented in medium-sized companies just like in large companies. He rejects both myths [19].

In addition to the size of the company, the literature indicates that the effectiveness of talent management depends on the company's strategy, the market and the branch in which the company is active [16].

Remarks: The exploratory review revealed that there are various factors that have an influence on talent management in a company. The size of the company appears to be a key factor. In addition, you need to understand the environment in which a company must assert itself. For this reason, company size and the brewing industry was examined in more detail as a differentiating factor (objective 1).

The comparative analysis revealed that the talent management process is not uniformly defined. However, it was possible to identify core elements that occur again and again. Basically, the aim is to fill key positions in the company. This should be achieved by attracting, identifying, developing, deploying, and retaining talent. For further processing, this is the basic understanding when talking about talent management (objective 3).

2.2 Employer Branding and Product Brand

Kahl states that an attractive employer brand is a prerequisite for attracting the right employees as part of the talent management process. The employer brand is developed through so-called employer branding [16]. Brenner defines employer branding as follows: "*Employer branding encompasses all strategic corporate measures for branding as an attractive employer in order to stand out positively from other competitors in the labor market*" (translated) [22]. This is intended to appeal to both the company's own employees (employee retention) and future employees (HR marketing). Building an employer brand is comparable to building a product brand [7].

"*A trademark is a name […] used to identify the products or services of a supplier or group of suppliers*" (translated) [23]. The aim should be for customers to "*literally snatch the products out of the company's hands*" (translated). This should be achieved with the help of so-called marketing. It should be noted that marketing does not only consist of "*advertising and selling*". Marketing begins before production with the identification of customer needs. Marketing accompanies the entire product life cycle to address new customers and retain existing customers [23].

The aim of marketing is to ensure that a product is not only perceived positively but also as unique [7]. Different characteristics must be developed to achieve this. Kanning has summarized the characteristics in a table and explained them in more detail using a product and an employer [7] (see Table 1):

According to Table 1, building an employer brand is an extensive project. At this point, the legitimate question can be asked as to whether this is at all beneficial.

Table 1 Characteristics of an employer brand compared to a product (translated) [7]

Characteristic	Product (Example car brand)	Employer
Name, Symbol, Design	Jaguar, jumping cat of prey, coupe shape, characteristic headlights, taillights, etc.	X AG, company logo, use of certain colors for company vehicles, letterheads, etc. "Corporate design"
Positive demarcation	Small car manufacturer, vehicles are rarely seen on the road, premium manufacturer, etc	100 years of successful company history without redundancies, world market leader, high profile, etc.
Loyalty	Customer doesn't even think about switching to another brand the next time they buy a car	Employees defend their employer against external attacks; remain loyal to the company even if attractive alternative offers are available
Satisfaction	Product meets or exceeds the needs	Employees enjoy working for their employer
Emotional connection	Customers are happy when they see their car, buy additional items such as key rings or umbrellas with logo	Employee feels with his employer, e.g., in difficult economic times; develops commitment
Concrete characteristics	Performance, fuel consumption, costs, resale value	Wage, working hours, voluntary social benefits, promotion opportunities, etc.
Symbolic characteristics	A feeling of sporty elegance, British automotive tradition, and distinction	A sense of tradition, reliability, and social responsibility, etc.

However, various research results show that the effort will be justified. Applicants have a huge need for information about their future employer. And they obtain the information via the channels they trust. And if the need for information cannot be adequately met, the employer loses the opportunity to build up a relationship with potential applicants in the first place [24]. Elsewhere, however, it was elaborated that "*[o]nly a small group of companies (<20%) use clear employer attribute signals to communicate their projected employer image*" [25]. This is alarming, because employer branding is particularly important at the beginning of the employer selection process [26].

Remarks: An essential component of employer branding is the right communication with the right content. If one compares the descriptions in Table 1, the characteristics "Name, Symbol, Design", "Positive Demarcation", "Concrete" and "Symbolic Characteristic" are likely to play a key role in the initial communication for both the product and the employer brand. How this communication should take place is explained further in Sect. 2.3.

2.3 HR Marketing

Recruiting personnel is a task in the talent management process (see Sect. 2.1). The idea of marketing has also been adopted in HR work. HR marketing is intended to "*develop human resources for the company in the long term*" (translated) [27]. It must be understood that the workplace is to be understood as a product that must be sold to employees on the labor market. It is essential that personnel planning is aligned with the personnel strategy, that an information base is created, and that communication is differentiated according to the various target grops [27]. Kanning distinguishes between four groups in his explanations: unskilled workers, skilled workers, specialists, and experts [7]. In principle, personnel marketing stands between the employer, potential applicants, and alternative employers. Research, development, and advertising must be planned and implemented for these three parties. As an employer, you need to know what the current and future needs of the target groups are. Are there differences in the target groups and how should your own company's image be? It is important to keep track of competitors' images and advertising strategies and what has been successful and less successful. Based on these findings, you can then further develop your own jobs and organization, which in turn should be compared with your competitors. Once you have developed your own approach and built it up accordingly, the right information must be published via the right channels to inform the target groups and consistently build up your own image. This in turn serves to highlight your own advantages and differentiate yourself from the competitors [7].

In 2012, more than 1600 people from different professional groups were surveyed on the possible communication channels. It was found that the company website was rated as the most appealing channel and was also used most frequently by the survey participants [7]. In the McDonalds Ausbildungsstudie 2019 with 1592 participants, the use of the internet continues to be a tried and tested means, even if the exchange with parents, friends and acquaintances received even higher approval ratings in the context of professional orientation [28].

The participants were also asked about their expectations. It was particularly important that the work was fun, that they had a secure job, and that the profession matched their own skills and inclinations. When asked about their motives for choosing a training company, it was particularly important to the participants that they have a good chance of being taken on after their training, that the work is not too far away from home and that there is a good working atmosphere. Industries are rated as attractive if they offer good prospects, job security and good earning potential. In a comparison of sectors, the IT, automotive and media industries are rated positively, whereas the food and beverage industry or gastronomy are only attractive to a few [28].

Finally, however, it must be considered that the aim of personnel marketing is not to achieve mass applications for vacancies in the company. It is much more important that personnel marketing can attract and win as few unsuitable and as many suitable applicants as possible [7]. If only "*positive recruitment messages*" (translated) [26] are conveyed, this could "*override useful self-selection mechanisms*" (translated)

[26]. Therefore, "*consciously selective employer characteristics*" (translated) [26] should be incorporated. However, hardly any research results are available on this [26].

Remarks: Based on the available findings, HR marketing and employer branding should not only be viewed from the perspective of one's own company, but always in the context of competing companies. It is therefore important to understand whether many individual approaches emerge or whether there is a main direction. It should be determined which and how the target groups are addressed. In addition, it should also be determined whether selection characteristics are also used.

Section 2.1 has already pointed out that talent management depends on the size of the company. Serious HR marketing is likely to tie up a lot of resources. For this reason, the following chapter will take a closer look at what can realistically be implemented by SMEs in this context.

2.4 Small and Medium Sized Enterprises (SME)

As of 01.01.2025, the EU has defined criteria for when a company is considered as an SME. The main criteria for this are the number of employees and the annual turnover or the annual balance sheet total. The EU has defined three categories: micro, small, and medium-sized [29] The corresponding thresholds can be found in Table 2.

Example: A company with more than 8 employees and an annual balance sheet total of EUR 1.8 million therefore falls into the microenterprise category.

In 2022, there were a total of 3,435,478 legal entities in Germany [30]. Table 3 shows how many units can be assigned to the respective size classes.

Section 2.3 has already pointed out that HR marketing can be resource intensive. The literature points out that especially in SMEs resources are limited [31, 32]. In their study, Richter, et al. found that you can only expect a medium-sized company

Table 2 EU thresholds for SMEs since 01.01.2005 (translated) [29]

Number of employees and	Turnover Euro/year or	Balance sheet total Euro/year
Up to 9	Up to 2 Mio	Up to 2 Mio
Up to 49	Up to 10 Mio	Up to 10 Mio
Up to 249	Up to 50 Mio	Up to 43 Mio

Table 3 Distribution of companies by size categories in Germany [30]

Company size	Number
Micro	2,982,397
Small	361,638
Medium	74,398
Large	17,045

to have its own HR department [33]. It was also found that in around a third of the participating companies, the owner or managing directors were responsible for personnel planning and recruitment [33]. In line with this, there are generally only limited options for strategic planning [34].

Remarks: HR marketing should be cost-effective, especially for SMEs. Internet presences are used by applicants (cf. Sect. 2.3). Therefore, every company should refer to the respective career opportunities on its website. Based on the knowledge gained here, it cannot be assumed that many strategic statements will be found on the websites of SMEs. This aspect is therefore not examined further.

2.5 German Brewing Industry

The German brewing industry has been steadily losing jobs in recent years. This reduction has occurred because of increasing automation and necessary structural adjustments due to falling sales figures. The decline in sales is due to socio-cultural and demographic changes. The brewing industry has reacted to this by increasingly offering mixed beer drinks and non-alcoholic beers. However, this could not stop the negative trend. Surprisingly, the number of smaller breweries has risen. However, this was offset by the closure of medium-sized breweries (50,000 to 1 million hectoliters annual output) [35, 36]. Maack et al. point out that the beer market is quite heterogeneous despite large corporations and is fragmented into local and regional submarkets [35].

After years of job cuts, the number of employees stabilized at 26,752 in 2014 and was back at 27,916 in 2022 [37]. The stabilization was justified by the fact that the possibilities of "*rationalization and automation*" (translated) [36] had been "*exhausted*" (translated) [36].

In 2022, there were 1507 breweries in Germany [38], whereby most breweries can be classified as SMEs.

In 2016, 9% of employees were under 25 years old, 51% between 25 and 49 years old and 40% between 50 and 65 years old [36]. 76% of employees had completed vocational training, 9% had an academic degree and only 10% had no degree [36]. Finally, it should be mentioned that the annual gross salary in the brewing industry was higher than in the beverage industry [36].

Remarks: Demographic change is likely to be a major challenge for the German brewing industry. As the proportion of employees aged over 50 was 40%, the question arises as to whether the expected departures can be compensated for by young employees. It is also questionable whether employees leaving the company can be compensated for by using more technology. Based on the study cited, this must be answered in the negative at this point. Trost already pointed out in 2012 that not enough STEM specialists are being trained in Germany [2]. However, technical, and natural science skills are important for the brewing industry. This means that the quantitative deficit could be exacerbated by a qualitative deficit. The breweries

therefore only have the option of actively recruiting the available junior staff. Especially as the orientation close to home applies not only to sales markets, but also to future employees (see Sect. 2.3).

This raises the question of how breweries present themselves on the Internet to facilitate a cost-effective initial contact with potential applicants. Based on the findings to date, it can be assumed that the breweries are likely to focus on their own region.

3 Research Method

The main goal was to determine which HR information is made available on the Internet by German breweries. This was realized with the help of a qualitative content analysis [13]. The data was collected in November 2023, with a particular focus on determining how the company's own employer branding and talent management are presented to the public. A total of 95 brewery websites from all German federal states were examined for this purpose. The proportion per federal state corresponded to the respective percentage of the number of breweries in the federal state in relation to the number of breweries in Germany. The absolute distribution can be seen in Fig. 1.

The sample of 95 breweries was compiled using a simple random sample [12]. The following website was used as the basis for this: https://www.biermap24.de/brauereiliste.php. There is a list of German breweries in alphabetical order and separated by federal state. The selection itself was made with the help of the following random generator: https://zufallsgenerator.net/. For Saxony, for example, 5 out of 52 listed

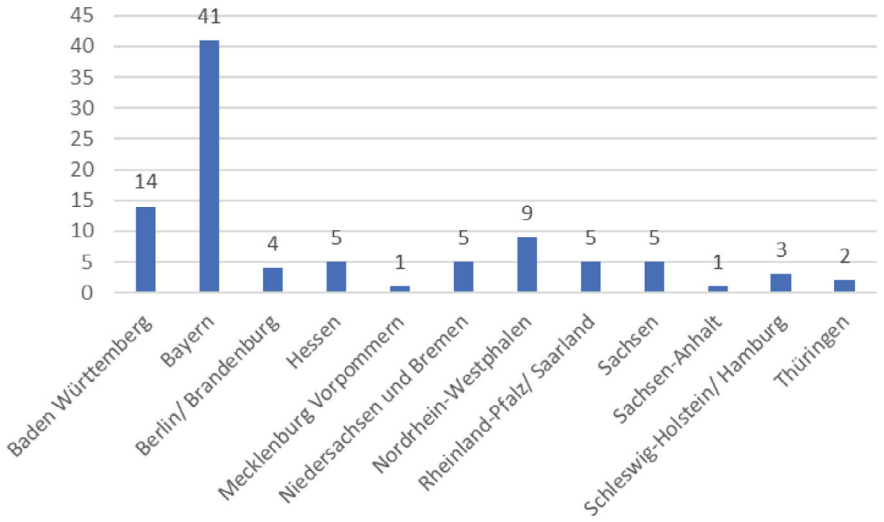

Fig. 1 Absolute number of brewery websites analyzed by federal state

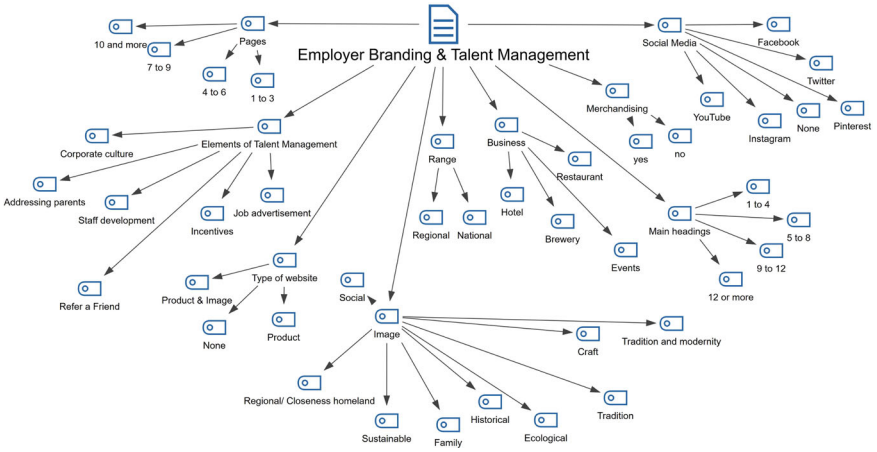

Fig. 2 Author's creation: MaxQDA code/subcode overview Employer Branding & Talent Management

breweries had to be selected. Therefore, the random generator generated 5 digits between 1 and 52. If a digit appeared a second time, the generation was repeated. In most cases, directly usable internet addresses were available. If this was not the case, the randomly selected brewery was searched for via Google. The information available on the websites was then transferred to a separate Word document. Once the data collection was complete, the Word documents were uploaded to MaxQDA and analyzed using a code/subcode model.

Based on the findings from Sect. 2, this code overview was developed deductively and inductively (see Fig. 2):

Using the code and subcode model, different aspects should be recorded. First, the code "Type of website" was used to determine whether the respective brewery operates a website and, if so, whether it is about the product or whether an attempt is also made to convey an image. In addition, the images that are maintained were evaluated (Code "Image"). The codes "Pages" and "Main headings" determined how much information the breweries provide. In addition to the websites, the strength of the presence in social media was also examined (Code "Social Media"). The "Business" code records whether the breweries stand-alone or other businesses operate in parallel. In addition, it was investigated whether the companies have a regional or national orientation and whether merchandising is carried out (Code "Range" and "Merchandising"). Finally, it was evaluated which of the selected elements related to the TM process are addressed on the website (Code "Elements of Talent Management").

4 Results

Section 4 presents the data collected separately according to general results (Sect. 4.1), results on employer branding (Sect. 4.2) and results on talent management (Sect. 4.3). To better assess the results, Sect. 4.4 provides a compact overview of the information provided online by the three most popular employers in Germany (2022).

4.1 General Results

The sample consists of a total of 95 breweries, 91 of which can be classified as SMEs. First, it can be stated that most of the breweries examined here have an Internet presence. 86 of the 95 breweries are present on the world wide web. The websites were consistently attractive, and some breweries even included short films. In addition to the internet, various social media are also used, with Facebook and Instagram being the most popular (Fig. 3).

As already explained, the descriptions available on the respective websites were saved in Word documents. The scope of the elaborated presentations can be seen in Table 4.

To obtain more than just a quantitative impression of the scope of elaboration, the subject areas (headings) presented on the websites were surveyed in a further step. The scope of subject areas can be seen in Table 5.

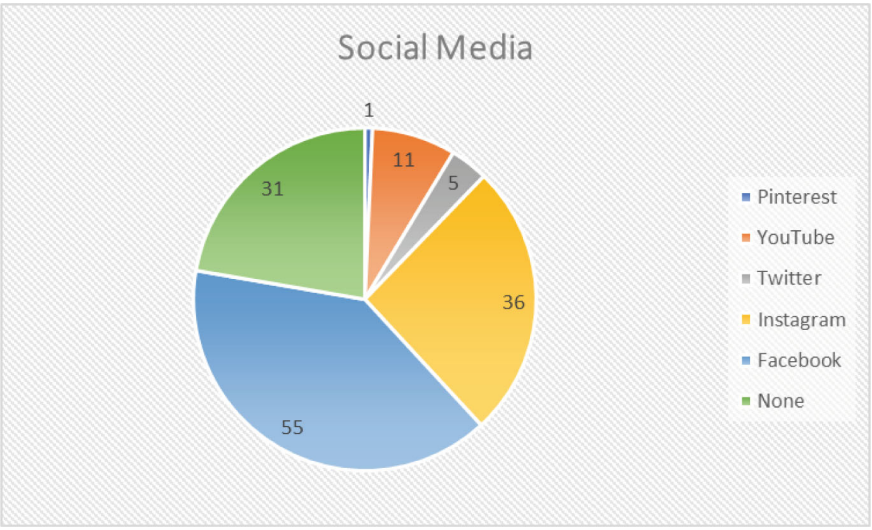

Fig. 3 Use of social media—distribution by provider

Table 4 Scope of elaboration of the websites—Number of pages

Number of pages	Number of breweries
1–3	79
4–6	5
7–9	1
10 or more	1

Table 5 Scope of development of the websites—Number of mean headings

Number of mean headings	Number of breweries
1–4	1
5–8	35
9–12	42
13 or more	8

Table 6 Scope of Other lines of business

Other lines of business	Number of breweries
Restaurant	55
Hotel	10
Events	38

In addition to the obligatory home page, the website provides an impressum, product information, current information, contact options, information on data protection, information on the general terms and conditions, career opportunities and information about the company itself. Furthermore, the evaluation of the websites revealed that 78 of the 86 breweries are regionally oriented. In addition to the actual brewery, additional lines of business are also operated, the distribution of which is shown in Table 6.

If you look at the other business sectors, you can also see a high degree of homogeneity here. The combination of brewery and restaurant is understandable. 54 of the 55 restaurants offer home-style cooking. Only one brewery restaurant deviates from this and combines a brewery with a pizzeria. The events on offer are also similar: brewery tours, brewery museums, tastings of various alcoholic beverages and the possibility of organizing different celebrations.

MaxQDA enables a similarity analysis of the documents with each other in which the similarity value can be between 0 (no similarity) and 1 (high similarity). With 9025 possible individual values, the average value is 0.76, with a minimum of 0.47 and a maximum of 1.00.

Remarks: In general, it can be said that the breweries surveyed have recognized the value of a good website. It should also be noted that the websites are very similar.

4.2 Results Objective 1 Employer Branding

The first step was to investigate whether the breweries only advertise the product on their website or whether the website is also intended to convey an image. The results of the study are clear. Of the 86 breweries that operate a website, only 10 breweries focus on providing information about the product. 76 breweries provide information about their products and try to convey an image. Which images are served can be seen in Fig. 4.

The presentation of the brewery's own history (69), its own tradition (66), its regional ties (51) and the fact that the brewery still practices genuine craftsmanship (50) are particularly well represented. The brewery's own history is also explained, even if the brewery has only existed for a few years. Even if tradition and history are of great importance, 34 breweries point out that they have also arrived in the modern age. In addition, the fact that they are a family business is often emphasized (44). Environmental awareness (26), sustainability (17) or social commitment (16) are mentioned less frequently.

26 of the 86 breweries engage in merchandising. For example, products such as glasses and clothing are sold, or the respective logo can be downloaded digitally. It is also possible to join fan clubs. One brewery appeals to customers to support its brewery financially on its website.

In addition to the previous examination, a frequency analysis was carried out using various keywords (Table 7).

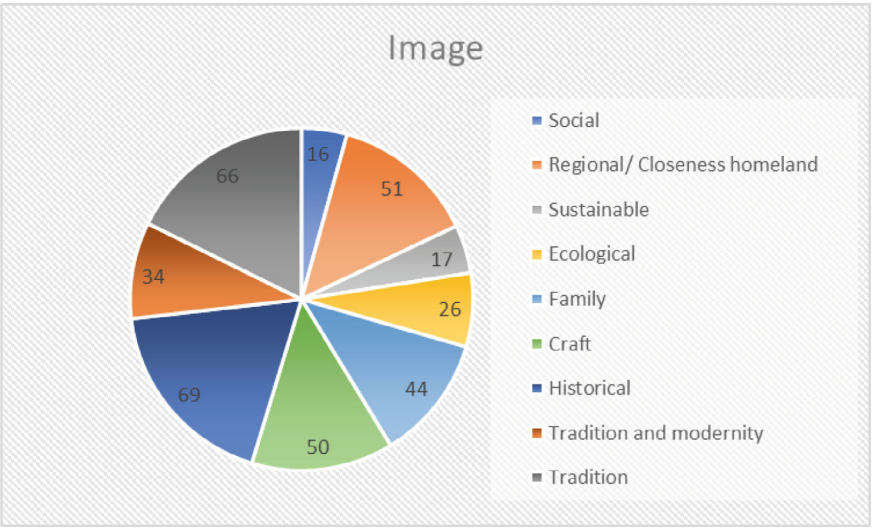

Fig. 4 Distribution of the detected images

Table 7 Overview of results for selected image keywords

Slogan	Number of hits	Number of documents
Tradition	181	56
Traditional	113	32
Family	230	44
Family business	17	13
Familiar	7	3
Environment	50	19
Environmentally friendly	17	5
Environmentally conscious	7	3
Sustainability	13	8
Sustainable	32	10
Modern	122	35
History	79	50
Historical	45	15
Regionality	12	11
Region	161	41
Regional	119	30
Home	50	26
Craft	80	36
Handcrafted	80	25
Braukunst	55	27
Comfortable	53	17
Quality	146	46
Freshness	204	36

Words such as tradition, family, history, and craftsmanship are mentioned very frequently and repeatedly in the respective documents. Regionality, quality and freshness obviously also play a very important role.

Remarks: The similarity identified under 4.1 also continues regarding the images presented. A basic direction can be identified in the external image: a company from the region with a history that manufactures its high-quality products using traditional craftsmanship.

4.3 Results Objective 2 Talent Management

If one compares the results with the results obtained here, only little HR information is shared on the websites examined (Fig. 5).

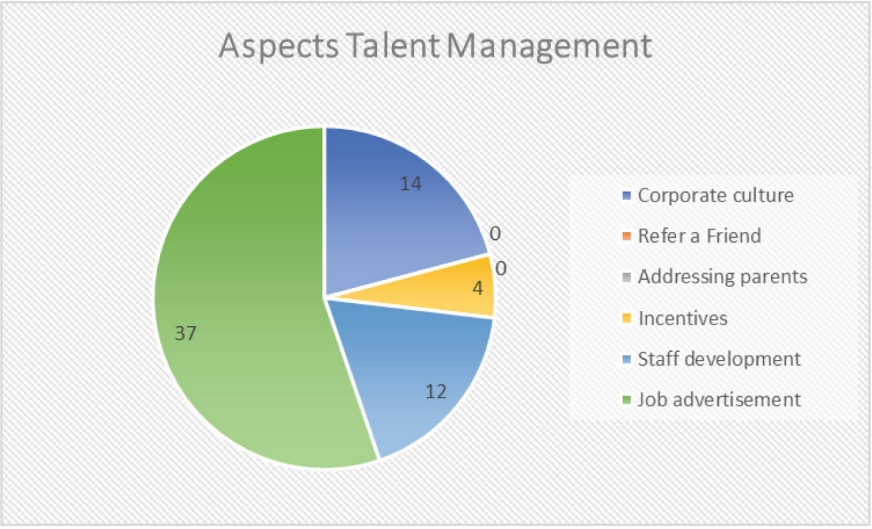

Fig. 5 Distribution of talent management aspects

Firstly, only 37 of the 86 breweries posted a job advertisement online at all. The target groups here were unskilled and skilled workers. Only 4 of the 37 breweries provided information on the incentives they offer to attract applicants. The most comprehensive offer presented by a brewery is listed below: Home brew, secure job, capital-forming benefits, Christmas/holiday bonus, bonuses for night/Sunday and public holiday work, mobility allowances, regulated working hours and digital time recording, free drinks and discounted lunch, team clothing, employee housing, training opportunities, bicycle leasing, company parties and discounts on purchases.

In 14 websites, the information on corporate culture is also geared towards employees and in 12 breweries, information on personnel development was found, although this was limited to the possibility of vocational training. No information could be found on further training and promotion opportunities within the company.

No evidence could be found that would indicate that friendships were being made for the purpose of recruiting staff. There is also no attempt to approach parents of future trainees.

In addition to this, a frequency analysis of corresponding keywords was also carried out in this context. Core terms from the talent management process—recruitment, identification, development, deployment, and retention—were not found. The term "career" appears twice in the explanations. Once in connection with the professional career of the current brew master and once as a subheading, which is then followed by brief explanations of the professional opportunities for future applicants in the brewery. The term "parents" was also found twice. However, both hits referred to the generations of parents in the company and not to the parents of future applicants (Table 8).

Table 8 Overview of results for selected keywords on talent management

Slogan	Number of hits	Number of documents
Corporate culture	0	0
Recruitment	0	0
Identification	0	0
Staff development	0	0
Staff deployment	0	0
Staff retention	0	0
Career	2	2
Refer a Friend	0	0
Parents	2	2

Remarks: Based on the available findings, it must be noted that the provision of HR information was not the focus during the survey period. It is therefore important to understand whether this is perhaps normal for German companies.

4.4 Insights into the Websites of the Three Most Popular German Companies in 2022

In June 2022, Stern magazine and Statista surveyed 43,000 employees to find out who the most popular German companies are. The car manufacturer Porsche came in first place, followed by the car manufacturer BMW and the chemical company BASF [39]. They provide the following information online (Table 9).

A comparison of the websites of the three most popular employees in Germany in 2022 shows that the content is also very similar. A lot of information about the company is made available via different channels. The company's own history, sense of responsibility, sustainability and modernity are clearly emphasized. Information about career opportunities is also adapted to the different stages of working life (school pupils, students, young and experienced professionals). It is noticeable that talent is automatically mentioned in relation to employees. Detailed information is also provided on the incentives that the respective employer offers its talents.

Remarks: A comparison of the breweries' websites with the websites of the large corporations presented here shows that the brewery websites evaluated need not shy away from comparison. There is a clear difference in terms of career information. This is not done with the same meticulousness as with Porsche, BMW, and BASF. It is interesting to note that the large companies automatically refer to talent on their career's pages. It was not possible to deduce from the available information how intensively these talents are supported once they have been hired. However, the task of recruiting personnel and thus part of talent management is obviously taken very seriously.

Table 9 Comparison of Porsche, BMW and BASF websites

	Porsche	BMW	BASF
Website	https://www.porsche.com/germany/aboutporsche/	https://www.bmwgroup.com/de/unternehmen.html	https://www.basf.com/global/de/who-we-are.html
Product information	Detailed	Detailed	Detailed
Presentation History	Detailed	Detailed	Detailed
Strategies	Explanations available	Explanations available	Explanations available
Key figures	Detailed	Detailed	Detailed
Image	Will be mediated	Will be mediated	Will be mediated
Careers page	Detailed	Detailed	Detailed
Differentiation according to entry age	Yes	Yes	Yes
Customized information according to the target group	Yes	Yes	Yes
Benefits	Yes	Yes	Yes
Social media	Facebook Youtube Instagram X Pinterest Linkedin	Facebook X Instagram Youtube Linkedin	Linkedin Facebook X Youtube Slideshare Instagram

5 Discussion

Section 5 discusses the results obtained in detail. It is important to establish whether the sample has produced findings that have already been found elsewhere.

5.1 Discussion General Results

95.7% of the breweries examined here can be classified as SMEs. Between 2012 and 2021, there were between 19 and 22 companies in Germany with 250 employees or more [40]. The proportion of SMEs in this study was around 97%. A similar size distribution was therefore achieved in the current study.

In 2023, around 67 million people in Germany used the internet [41]. A study conducted by ARD and ZDF in 2023 found that around half of people in Germany use social media on a weekly basis and a third even use it daily. People under the age of 30 use social media even more intensively and use several platforms [42]. The use of the internet and social media was recommended to breweries in a professional magazine in 2023 to reach their target groups [43]. 90.5% of the breweries evaluated

here have a website and 57.9% are present on FACEBOOK. Some of them are also represented on several platforms. It can therefore be stated at this point that the breweries examined here have a good chance of reaching their target groups.

90.7% of the breweries surveyed are focused on their own region. This result confirms the findings from the literature. The German brewing industry is strongly oriented towards the German domestic market and regional markets [40].

63.9% of the breweries surveyed operate a restaurant or tavern alongside the brewery. This combination makes sense, as the services on offer complement each other very well. On the other hand, it must be borne in mind that beer consumption has been declining for years. While more than 150 L of beer were still consumed per capita in the mid-1970s, the amount has gradually decreased over the years to 92 L in 2021 [40]. Regionality also plays a role in connection with beer sales. While the overall market is in a difficult situation, growth potential is still seen in regional beer specialties [40].

A survey commissioned by the German Hotel and Restaurant Association (DEHOGA Bundesverband) found that the hospitality industry plays a key role in the social fabric of the region. With high approval ratings, it was found that the hospitality industry promotes the attractiveness of the region (54.6%), enables further cultural and leisure activities (57.3%), makes the region livelier and more dynamic (58.4%), is an important meeting point for communication (59.3%) and reflects regional tradition (60%) [44]. The current data collection has shown that the breweries examined here are quite homogeneous. As people's needs are basically similar and the importance of regionality is also emphasized in the study of restaurants, it is logical that many breweries and restaurants have a regional focus.

Remarks: The comparison between the data collected and the data from the literature leads to the conclusion that the sample drawn allows conclusions to be drawn about the population. Every brewery should ensure that it has its own website and social media presence, as these channels can generally be used to reach its own target groups cost-effectively. Establishing your own company in your own region seems to be a promising strategy. A fundamental change in strategy should therefore be carefully considered. Gradual adjustments, such as switching from home-style cooking to Italian cuisine, for example, should be feasible in principle.

5.2 Discussion Objective 1 Employer Branding

88.4% of the breweries surveyed not only provide information about products, but also try to convey an image with their website. Their own tradition, family and history, ties to the region and high-quality products play a key role in this (see Sect. 4.2). Table 1 shows examples of how product image differs from employer image. Table 10 shows the different characteristics based on the results of the data collection:

In his overview, Kanning differentiated between product and employer branding based on seven characteristics [7]. In the current study, all characteristics were identified for the product image, but only four for the employer image.

Table 10 Comparison of product and employer branding based on the breweries examined

Characteristic	Product	Employer
Name, Symbol, Design	Name, Crest	Name, Crest
Positive demarcation	Taste, quality and freshness, bottle shape, variety of beers, genuine craftsmanship	Company size, own history and tradition, regional affiliation, sustainability, environmental friendliness and social commitment
Loyalty	Merchandising	No information
Satisfaction	Taste, quality	No information
Emotional Connection	Merchandising	No information
Concrete characteristics	Regional and high-quality raw materials, quality promise	Wage, working hours, voluntary social benefits
Symbolic characteristics	Traditional and handcrafted production	Tradition and local affiliation

37 companies have advertised vacancies on their websites and only 4 have explained what benefits future employees can expect. At the time of the survey, only 9 companies had advertised jobs for the brewery. They were mainly looking for staff for restaurants and hotels. This result corresponds to a different study result. Stracke et al. found that many breweries are only hiring a few new employees despite a shortage of staff. This is explained by the high-cost increases and the unclear economic outlook. Technical adjustments and the use of temporary workers are currently favored [40].

A comparison of the age structure in breweries between 2012 and 2021 shows that the group of employees aged over 50 has risen from 35 to 44% and the group of employees aged under 25 has fallen from 9 to 8% [40]. According to the companies themselves, they have found that with a good corporate image and good working conditions, they have no problems recruiting trainees [40]. Due to the prevailing age structure, this will certainly become even more important.

However, despite the need, it should not be forgotten that the right applicants should be approached rather than as many as possible [2, 7].

In their concluding remarks, Stracke et al. recommend that employer attractiveness must be increased if companies want to be successful on the labor market in the future [40]. One way of managing incoming applications would be to target different groups [45].

Remarks: 88.4% of breweries want to convey an image with their website. Derived from Table 10, the breweries are primarily concerned with building the product image. Whether the development of an employer brand is consciously pursued or whether this is an additional result of the actual intention cannot be assessed at this point. Nevertheless, most of the breweries examined here have already created the digital basis to present themselves successfully on the labor market. The addition of existing career opportunities and incentives should not pose a challenge if recruitment

becomes significantly more difficult in the coming years. In addition to this, employee perspectives could be recorded to gain a better insight into the company.

And after a successful approach, it is imperative to deal with the applicants correctly, which can be achieved through appropriate talent management.

5.3 Discussion Objective 2 Talent Management

If one defines the talent management process through the steps of discover, attract, develop, promote, deploy and retain (see Sect. 2.1), one comes to the conclusion that this is not reflected on the websites examined. 43% of breweries provide information online about job vacancies and only 4.7% about the benefits that applicants can expect if they join the respective company. This means that the information provided by the breweries is basically comparable to the information provided by the three large companies (see Sect. 4.4), even if these large companies provide much more extensive information about opportunities on their career's pages.

But is it even necessary for companies to provide information about a holistic talent management process? Von Walter notes in his comments that applicants have different information interests in the course of their employer selection [26]. Porsche, BMW and BASF go into great detail about the application process on their websites, while BASF provides additional information about onboarding (cf. https://www.basf.com/global/de/careers/application/onboarding.html). It is therefore questionable whether there is any added value for a company if all development opportunities are explained before recruitment. To make matters worse, development and promotion opportunities are limited, especially in SMEs [19]. And the majority of breweries fall into the SME size category [40].

Remarks: Based on the knowledge gained here, it does not make sense to describe the entire talent management process of the respective company. The description of onboarding is a useful addition to the points from Sect. 5.2.

6 Conclusion

Even if Stracke et al. assume that staff will be laid off in the future, the shortage of skilled workers will remain a challenge. To overcome this problem, they recommend, among other things, increasing employer attractiveness [40].

Whether the shortage of skilled workers has already reached breweries to any great extent cannot be conclusively assessed with the current study. However, as only nine breweries were looking for brewers during the survey period, this could be answered in the negative at this point. It is therefore essential that breweries are now aware of when older employees will leave their own company and how likely it is that the vacant position can be filled again and how quickly this can happen. If

the answers to the last two questions indicate problems, the employer image should be cultivated and communicated to the outside world as quickly as possible.

This means that breweries that have not yet set up a website should do so as soon as possible. For those that already have an online presence, they should not only list vacancies, but also present themselves as an attractive employer. The characteristics in Table 1 can serve as a guideline. In addition to this, it should be noted that, alongside the correct preparation of information, rapid processing of incoming applications is a key factor in the recruitment process [46].

As the recruitment of young trainees will become important due to demographic change, their needs should be considered in more detail. Lehmer et al. highlight four categories that should be considered in particular in this context: Mobility, housing, monetary incentives and future prospects. One aspect of future prospects is promotion/training [47]. These two keywords justify the need for internal talent management within the company, which goes beyond the task of stand-alone personnel development. Employer image and talent management thus merge and make a significant contribution to the continued existence of the respective company.

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Integrated Analysis of Web Advertising Strategies for Corporate Branding

Yuriy Syerov

Abstract This article is a significant contribution to education and advertising, as it presents a comprehensive analysis of international firms' increasingly important advertising practices over a long period. The paper focuses on developing information and advertising materials for the successful branding of secondary schools, a topic of growing interest in the field. Using an integrated analysis framework based on existing literature, it is concluded that the most effective means of PR for the school is the production and distribution of printed materials. In addition, it provides an analysis of the regulatory documents governing the school's activities. The results show that using promotional materials and the right strategy and design significantly improves the brand of secondary school, attracts more students and support from the community, and promotes the school's services.

Keywords Educational competitiveness · Information and advertising strategies · School branding · Digital · Printed material · Marketing in educational institutions

1 Introduction

In the modern world, competition among educational institutions is very high. Effective information and advertising activities not only help to create a positive impression of the school and attract the attention of parents and potential students but also demonstrate the advantages of the educational institution, including the school. A school is a community where all its members must be well informed. Information work helps to avoid misunderstandings between teachers, parents, and students. Information communication helps to positively influence public opinion and maintain the educational institution's reputation. In the digital age, it is essential to ensure

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that information about the school is available on the Internet and through mobile applications and social networks. This contributes to the convenience of consumers and expands the audience.

Information and advertising support are important and relevant tools for achieving success in the school's educational activities and maintaining and strengthening its position in the modern educational environment.

Information and advertising materials were developed for successful corporate branding, such as information booklets, a logo, brochures, business cards, information materials, and presentations.

2 Related Work

The researchers examined the primary cultural values portrayed in magazine advertisements across various product categories. They compared the differences and similarities in how often these dominant cultural values appeared in print magazine ads [1–3]. The analysis revealed that there are common dominant values depicted in magazine ads in both countries. However, there are statistically significant differences in the frequency of their occurrence for several observed values. As a result, advertising campaigns in each country should be carefully assessed based on the target market, cultural and environmental factors, and the nature of the product.

The researcher also focused on two complementary detailed advertising information processing modes. They investigated two determinants of the stimulation of advertising images and their analysis. The results show that the use of consumer images is related to the perceived novelty of the advertising stimulus, while analysis is related to less favorable advertising content. In turn, product-related effects and purchase intention are positively related to images and negatively related to analysis.

Scientists studied the trends and experience of international firms in green advertising. It was found that consumer skepticism about the reliability of green advertising is growing worldwide. The researchers provided a comprehensive assessment and analysis of trends in green advertising practices of international firms over the past 20 years. The study identifies 473 international green advertisements from 1988 to 2007 and their content. They are analyzed on five main axes: advertiser profile, targeting functions, message aspects, characteristics, and situation points. The content analysis revealed significant trends in all the main areas studied and identified essential interaction effects between certain dimensions of green advertising. Research on green advertising has mainly focused on domestic rather than international advertising. This study fills the gap by systematically evaluating international green advertising over a long period and using an integrated analysis framework based on existing literature. The researchers also explore potential interaction effects between the key dimensions describing these advertisements.

The research [4] concluded that colleges and universities usually need better advertising jobs. Challenges arise when considering advertising, including the special circumstances surrounding higher education, but these challenges can be overcome.

This article addresses the steps in the advertising process—creating an advertising plan, who prepares the plan, and similar issues—and positions advertising as part of an institution's overall marketing strategy [5].

Peculiarities of the mass media functioning in the modern world [6, 7] over a long period and the role of all Ukrainian publications in uniting the country's information space concerning the works studied by many well-known scholars. The study focused on the features and methods of printing advertising and considered printing as part of advertising activities [8].

In [9], the researcher studied the issue of choosing advertising media for publishing products. The researcher studied the specifics of the advertising activities of the world's institutions. He argued the relevance and necessity of researching this issue. Sustainability, competitiveness of higher education institutions, and success in the education market are the keys to advertising activity. The following advertising functions of advertising educational services are introduced [10–12]: information function, value-oriented function, and communicative function.

Scientists still rarely study the specifics of the advertising activity of higher education institutions:

- Aspects of marketing practice of higher education institutions [13],
- the purpose of marketing in the development of communications in the market, development of communication strategies of educational institutions [14],
- special online marketing of educational services [15–17],
- positioning, popularization [13, 18], and branding of educational institutions [19–21].

Domestic scientists are studying applied aspects of the advertising activity of educational institutions [22]:

- Modern trends in planning advertising campaigns for educational institutions,
- gathering a contingent of students from higher education institutions,
- specifics of applicants to higher education institutions for study,
- Prospects for forming competitive advantages of popularizing higher education institutions.

The table in the figure shows the Media plan for a higher education institution's advertising campaign for the year [14]. The mechanisms for analyzing the media sphere's functioning are considered in the works [18, 23].

The systematic methodology and techniques of studying mass communication in the informatization of society. The cultural peculiarities of modern texts are reflected in the modern research. The peculiarities of the functioning of new media are reflected in research. A review of publications on this subject showed that the works of domestic and foreign researchers in the field of stylistics, journalism theory and discourse theory, mass communication theory, and generation theory formed the study's theoretical basis.

The least researched in Ukrainian science are the problems related to the functions and importance of advertising activity for the growth of competitiveness and the formation of the image of higher education institutions [13, 24]. The most important

types of commercial advertising are shown in the figure, according to which the types of advertising are classified by the following criteria [25]: purpose, type of sponsor, target audience, market segment, range of influence, object of advertising practice [26, 27], method of influence, channel of perception, nature of influence, function and purpose, type of influence.

Advertising publications from the point of view of documentary studies. Babenko D. studied new advertising types of tourism enterprises [4, 10, 28]. The mass media (newspapers, magazines, television, radio, and the Internet) are the main carriers of informational advertising messages and absorb almost 60% of all funds spent on advertising together. Firms use the media to inform potential customers. Specialized printed materials are one of firms' most important means of advertising. Businesses publish illustrated brochures, booklets, catalogs, leaflets, etc., independently or with similar companies. A separate type of specialized printed matter is price lists, which publish prices and rates for goods and services. The methodology is based on a comprehensive analysis of the visual characteristics of comics as a source of non-standard visuals and the principles of using these visuals [29] in advertising and print product design. It is proved that the discussed visuals of comics can be effectively used in advertising and printed products. Using comic book visuals can enhance the process of designing print advertising samples, making them visually attractive and introducing a spark of originality to attract and retain the attention of a potential customer. Therefore, this approach to the design of advertising and print products should be developed further.

The information and advertising representation of the functioning of public organizations, namely the current means of positioning public organizations. She also studied the characteristics of advertising through social networks and commercial advertising in print.

Scholars have also studied the purpose of graphic design in advertising. They studied the graphic design of letterheads and envelopes, popularization in the media [39], outdoor advertising, posters, presentations, catalogs, flyers, leaflets, booklets, proclamations, calendars, notebooks, pens, cups, etc. Graphic design can be conditionally divided into the design of advertising graphic products and representative (or branded) graphic products. In different situations, the design of advertising printed materials may include both graphic design and layout, photography, scanning slides, photos or printed originals, image processing, collage creation, and sometimes even copywriting services and content development that are not directly related to design but are actively used in the design of advertising printed materials. The design of representative printed promotional products is closer to the development of corporate identity than to the printing design of individual elements of corporate identity—letterheads, envelopes, business cards, corporate folders, etc.

School branding is a set of strategic actions and marketing practices [30, 31] that create a unique and recognizable image of the school, its positioning in the education market, and its interaction with the audience. It aims to increase the school's attractiveness, reputation, and recognition among parents, students, teachers, the community, and other stakeholders.

Corporate branding helps to create a positive impression of a school and define its uniqueness in the education market. It helps to attract new students, talented teachers, and partners with the community, which in turn contributes to the school's educational level and success. The main aspects of the school's branding include:

- Create a clear identity for the school and highlight its core values, mission, and vision. This helps to establish how the school differs from other educational institutions.
- Develop a logo, color palette, style, and graphic design to reflect the school's brand and be used in all information and advertising materials.
- Develop a communications plan, including internal and external communication. This includes communication with parents, students, teachers, and the media and social media.
- Engage with parents, the community, and other stakeholders to garner support and participation in school life.
- Maintaining and improving the quality of education to meet the expectations of students and parents.
- Promote the school's brand using marketing tools such as information booklets, brochures, websites, and social media.

The development of printed materials is crucial for school promotion. Figure 1 shows the key aspects and importance of their use.

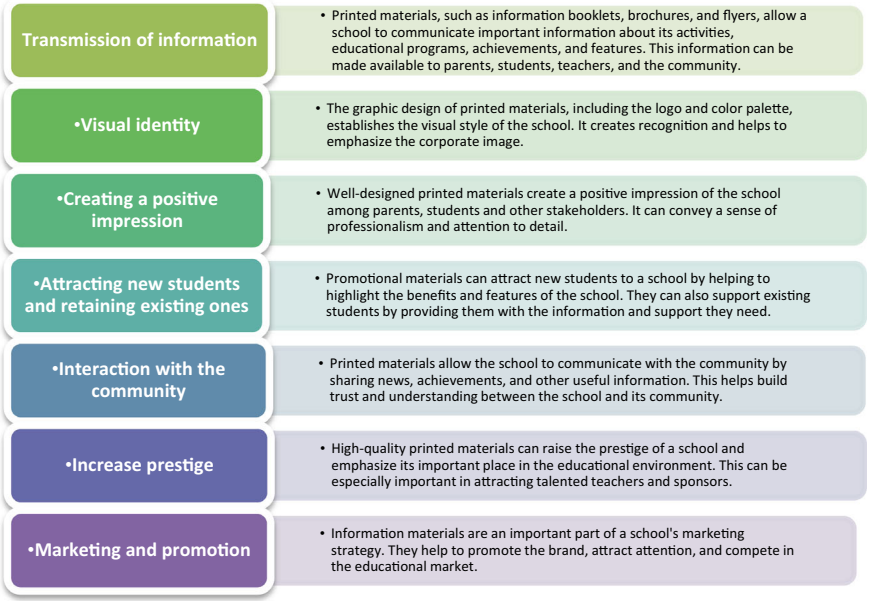

Fig. 1 Key aspects and importance of using printed materials for schools

Developing printed materials to promote a school helps to create a strong and recognizable brand that attracts students and supports and raises its status in the educational environment. Schools and educational institutions use different printed materials for advertising and informational purposes. Here is a list of some of these types and their advantages:

- Posters can be large and prominent, which helps to attract the attention of students, parents, and teachers. They effectively convey graphic information and can be used to promote events, activities, or curricula.
- Brochures provide detailed information about the school or its programs. They can be handed out at parent-teacher conferences or other events, making readers more familiar with the school's offerings and benefits.
- Flyers are well suited for distributing brief information about events, promotions, or important dates. They are usually smaller than booklets and can be distributed to various audiences.
- Banners placed on the school's walls or grounds can attract attention for a long. They can contain vivid images and attractive designs.
- Brochures can be used to present a school, its history, programs, and teachers in detail. They create a professional impression and allow us to familiarize readers with all the necessary detailed information.
- Newspapers or magazines created by the school can engage students in writing and editorial efforts and allow for greater publicity of school events and achievements.
- School notebooks and notebooks with the school logo can be used as gifts for students, parents, or teachers. They also help to raise awareness of the school.
- Postcards can be used to contact parents, students, or teachers in person. They can contain important information and help draw attention to specific issues.
- Some schools may create special publications, such as admission catalogs or textbooks with information about school programs.

When choosing the type of printed materials to advertise an institution, it is important to consider the target audience, the purpose of the advertisement [32], and the available budget. Combining different types of printed materials is the most effective approach to achieving the goal. This section analyzes scientific and educational sources on developing promotional products for educational institutions. It also reviews legislative and regulatory acts in the subject area.

3 Analysis of the State of the Subject Area

This section analyzes the enterprise of Lviv Secondary School 22, provides a general description of the school's activities, and analyzes the school's regulatory documents. With the help of new ideas and continuous improvement, school is enhancing its brand and becoming more popular among the public. The school has developed a new website. The main page is shown in Fig. 2.

Fig. 2 Website of secondary school 22 in Lviv

Development of information and advertising materials for successful branding of the school requires a comprehensive and professional approach. Here are some important steps and recommendations:

- The focus of any brand begins with understanding the audience. It will help determine which groups (students, parents, teachers, partners, etc.) will perceive your materials and develop them with their needs and expectations in mind.
- The logo is important to the brand. It should be easily recognizable and reflect the school's core values and characteristics. Specialists also develop a corporate identity that includes colors, fonts, and graphic elements to simplify the perception of a brand.
- These materials are used to introduce the school and its services. They should be aesthetically pleasing, informative, and easy to read. Include photos, infographics, and short, clear descriptions with each material.
- Create textual and visual content for information materials that emphasize the company's key advantages, such as quality education, professional teaching staff, and modern equipment.
- Develop presentations that can be used at meetings with parents, exhibitions, or other events. They should be informative, exciting, and easy to understand.
- Before publishing any materials, collect feedback from different audience groups to ensure they are compelling and exciting for the target audience.
- Constant updating: The brand is evolving, and materials must be updated to reflect changes in the company and society.
- In addition to traditional materials, actively use digital channels such as websites, social media, and email newsletters to reach a wider audience.

Analysis of the subject area objects and their interrelationships in a company requires considering the main elements that affect the learning process and the company community. The main objects of the subject area at the company are the following:

- Students—this is the main subject of education and upbringing at school. Students of different age groups have their characteristics, needs, and requirements.
- Teachers—teachers play a key role in imparting knowledge and educating students. They design and deliver lessons, assess students' work, and contribute to their development and formation.
- Curriculum is the set of subjects and materials a teacher uses. It is based on educational standards and contains learning goals and objectives.
- Methodological materials and resources—these are textbooks, teaching aids, computer programs, laboratory equipment, and other resources that teachers use to teach.
- Parents and public organizations—Parents are essential stakeholders in the educational process. They can participate in school decision-making and improve the quality of education. NGOs can influence company policies and support company initiatives.
- Administration and management—the school administration organizes work, allocates resources, and resolves administrative issues.
- Financing and budget—company funding includes allocating funds to meet educational and training needs.

The relationships between these objects in a company can be as follows:

- Teachers led the learning process while students receive information and participate in it. The interaction of these two entities is central to the school context.
- Teachers use curriculum and materials to develop lessons and ensure quality learning.
- Parents can influence the educational process by communicating with teachers and administration and supporting school projects and initiatives. Public organizations can run joint projects with the company.
- School administrators determine how funds are allocated to meet all needs, including curriculum, equipment, teacher salaries, etc.

All these objects and their interrelationships form a complex system that aims to provide quality education and upbringing for students. Effective communication, cooperation, and mutual understanding between all participants in the company process are important factors for success.

Information and advertising activities are key elements of a school's effective operation. They are also the basis for creating and maintaining the school's brand in the community. Table 1 describes the types of printed materials, their main attributes, characteristics, and examples of successful company branding.

These types of printed materials, together with the right strategy and design, can significantly improve the school brand and attract more students and community support.

The principal activity of the enterprise "Secondary General Education School 22 of Lviv" is providing educational services. This section analyzes the school's

Table 1 Types of printed materials for successful corporate branding

Type of printed matter	Main attributes	Characteristics	A successful example
Information booklet	• Images of the school and its infrastructure • Description of educational programs • Feedback from teachers and students • Contact information	The information booklet is used to distribute detailed information about the school to parents and students	An information booklet was created with clear photos and a clear description of the school, its programs, and its achievements
Logo	• Graphic display of school symbols • Color palette • Text element (school name)	The logo is the visual face of the brand and should be easily recognizable and representative	A logo with a unique design that reflects the school's values and identity
Brochure	• Special topics (e.g., annual report or information for new students) • Visually appealing design • Content content	A brochure helps to convey important information to a wide audience in an attractive way	A brochure presenting the school's achievements and plans with high-quality illustrations and informative articles
Business card	• Name and position of the company representative • School logo • Contact details	A business card makes storing and sharing contacts and information about the school easy	A business card with clear information and a professional design that reflects the school's corporate style
Information presentation	• Images and text information • Animation and sounds • Interactive elements	A presentation allows one to present information and impress the audience effectively	Interactive presentation using modern technologies [11] to demonstrate the school's achievements and capabilities

structure and activities, the subject area's objects, and their relationships. It also analyzes the regulatory documents governing the company's activities.

4 Methods of the Study

In system analysis, it is necessary to study information processes in addition to the system's functions and elements. System analysis's main feature, distinguishing it from other scientific disciplines, is a comprehensive study of systems.

The systemic approach determines that research is conducted on the material, energy, and information sides when studying any object as a system. The study of the information side of the system is the study of the system's goals, the organization of the system's signaling system, information flows, and control. Information plays a significant role in the system. While material and energy flows form the basis of the system, information organizes its operation, provides connections between elements, controls the system's operation as a whole and its parts, and ensures that the system performs its functions. As a rule, system analysis is carried out at enterprises' request and aims to improve economic efficiency, reduce production costs, improve product quality, and increase competitiveness. For this purpose, a detailed analysis of all enterprise components, their work, the relationship between individual activities, and the costs of performing the work is performed.

In information models, unlike functional models, the main element is data, which is represented as blocks, and data operations serve as interfaces—arcs. Interface arcs combine data. They are certain works, operations on objects, and information. Information models are often called data models. According to the accepted terminology, data is understood as information and objects in the system. Data flows are the transfer of information and the movement of objects in the system. Sometimes, they are distinguished into material and information flows, and this difference is introduced into the model by different notations. In information models, all flows are represented by arcs. Different notations are used for material flow arcs, and information flows in some data models. There are many more information models than functional models. This reflects that information plays a significant and sometimes decisive role in systems.

The Entity-Relationship Data Model (ERD model) is crucial in system analysis and is widely used in developing and using information systems.

The ERD model (Fig. 3) of information and advertising support for the activities of "Secondary school 22 of Lviv" contains six entities:

- ***The School entity*** contains the following attributes:
- # School code
- Number of students
- Number of employees
- Rank in the rating
- Address

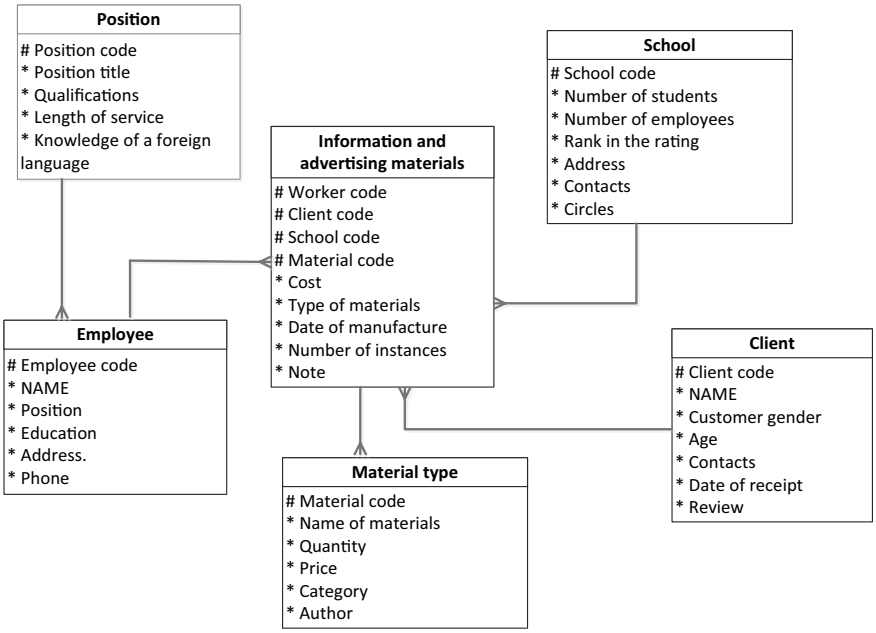

Fig. 3 ERD model

- Contacts
- Circles
- The "***Employees" entity*** contains the following attributes:
- # Employee code
- NAME
- Position
- Education
- Address.
- Phone
- The ***Client entity*** contains the following attributes:
- # Client code
- NAME
- Customer gender
- Age
- Contacts
- Date of receipt
- Review
- The "***Position" entity*** contains the following attributes:
- # Position code
- Position title
- Qualifications
- Length of service

- Knowledge of a foreign language
- The "Information and advertising materials" entity contains the following attributes:
- # Worker code
- # Client code
- # School code
- # Material code
- Cost
- Type of materials
- Date of manufacture
- Number of instances
- Note
- The "***Material type" entity*** contains the following attributes:
- # Material code
- Name of materials
- Quantity
- Price
- Category
- Author

The above six entities have mandatory attributes ("Employee code," "Customer code," "School code," "Position code," and "Materials code"). They are represented by a list of names of these attributes in the middle of the rectangle of each of the entities. The attribute reflects the type of characteristics or properties. For example, consider one of the entities, "Information and advertising materials." The key attributes are Employee code, Client code, School code, Material code, Cost, Material type, Date of manufacture, Number of copies, and Note. Each attribute of the entity has a unique name. Now, let us describe the relationships between entities in detail. A one-to-many relationship exists between the "Client" and "Information and advertising materials" entities since a client can receive one or more information and advertising printed materials. There is a one-to-many relationship between "Promotional materials" and "Types of materials" because the school uses many promotional materials to publicize its activities.

The relationship between the "Position" and "Employees" entities is one-to-many since several employees can simultaneously work in the same position.

A one-to-many relationship has been established between the entities "Employees" and "Information and advertising materials" since one employee can provide materials to develop one or more advertising materials for the implementation of information and advertising support for the school's activities. A one-to-many relationship has been established between the entities "School" and "Information and Advertising Materials" since the school uses many information and advertising materials to support the information activities of the secondary school. The entity-relationship data model identifies the most essential elements, and the relationship between them is established.

The built functional model is the result of the analysis. It greatly facilitates studying the company's operations and provides the necessary data to improve its activities and performance. Building a model allows us to identify system functions repeated at different stages. Performing the same functions by different parts of the system reduces the efficiency of its activities, as it introduces unnecessary duplication of work. When building a model, syntactic control does not allow the introduction of blocks with the same work. The model analysis also reveals functions that should be performed but are not performed. This leads to disruptions in the normal cycle of the system's operation, downtime, and narrow cities. By introducing changes to the system to correct these identified shortcomings, we can significantly enhance work efficiency, offering a promising outlook for the system's potential.

The functional model's main aspect is the representation of data flows using data flow diagrams (DFD). These diagrams (Fig. 4) play a crucial role in describing the data flows between individual system activities, providing reassurance about the system's information handling.

Material flows include, for example, raw materials, supplies, workpieces, finished goods, equipment, vehicles, etc. Information flows are information about orders, market data, availability of raw materials, spare parts, warehouse stocks, work performed, production bottlenecks, manufactured products, cost information,

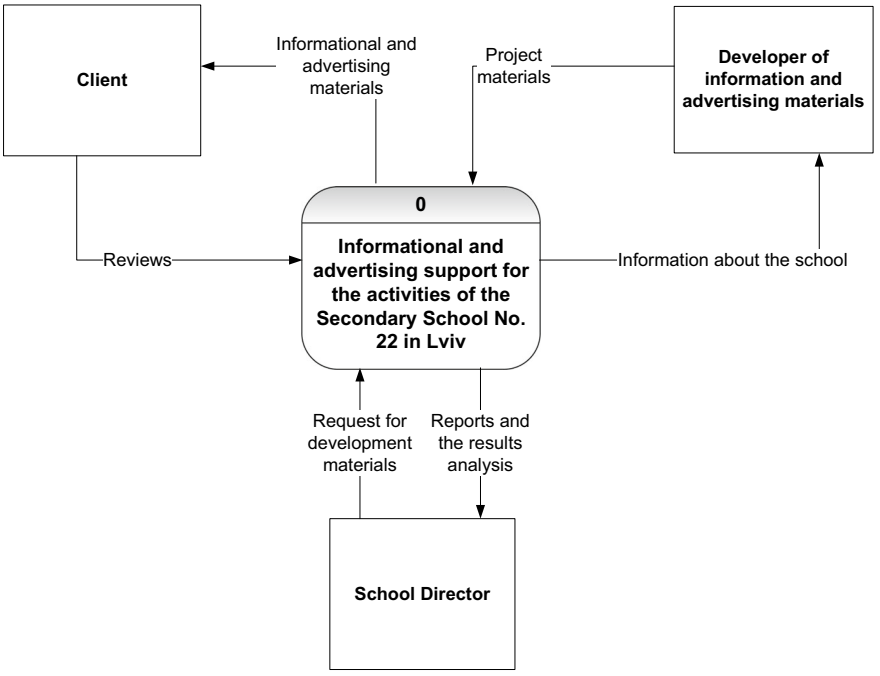

Fig. 4 DFD diagram of data flows of the process "Information and advertising support of the activity of secondary school 22 in Lviv"

management teams, etc. DFD diagrams are functional models because their main elements are activities, and data act as interfaces that connect activities. Unlike IDEF0 diagrams, they focus more on data flows. While remaining functional models, they allow you to display the information side of the system in more detail. Namely, the data flows in the system, their decomposition, and the data transmission and storage sequence. As a rule, these diagrams are included in the functional model as a supplement to IDEF0 diagrams at a lower level of decomposition. Such an addition makes the system functions more understandable, expands them, and details them in the information aspect.

Considering the structure and main processes of secondary school activity (Fig. 5), a contextual diagram of information and advertising support for schools has been built.

The main elements of a DFD data flow diagram are as follows:

- work (information processing functions);
- data flows (arcs of input and output values);
- data warehouses;
- external entities:

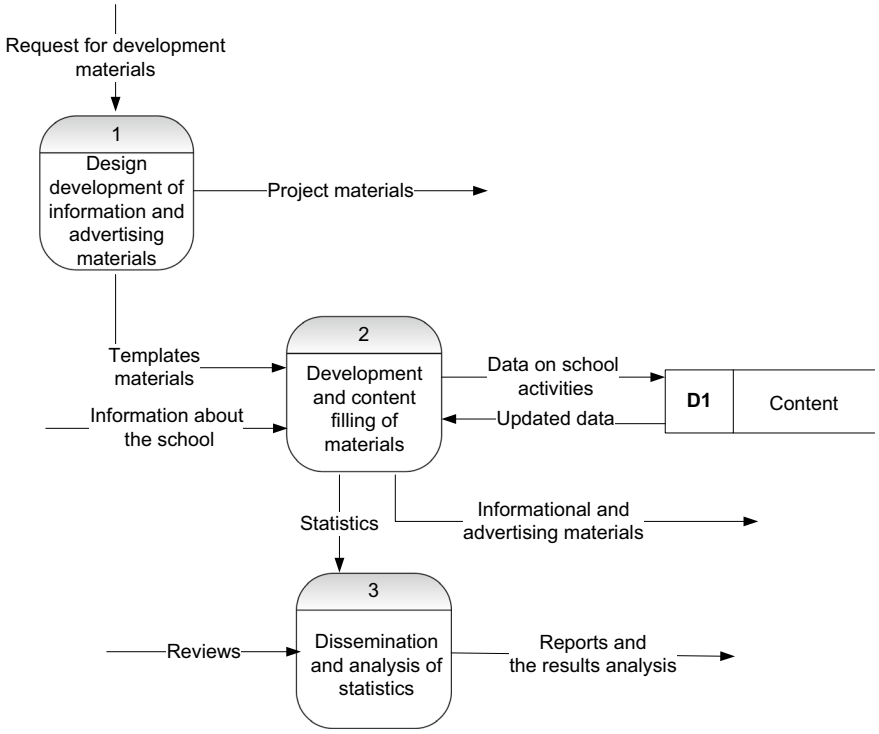

Fig. 5 Decomposition of the process "Information and advertising support for the activities of secondary school 22 in Lviv" of the first level

Developer of information and advertising materials
Client;
School principal.

Contextual diagram of information and advertising support for the activities of school (Fig. 5) contains three external entities: "Developer of information and advertising materials," "Client," "School principal," and the following main data flows:

- Information and advertising materials,
- Reviews,
- Draft materials,
- Information about the school,
- Request for materials development,
- Reports on the results of the analysis.

Having decomposed the data flow diagram (of the process "Information and advertising support of the activities of School"), we get the following systems (see Fig. 5):

- Design of information and advertising materials,
- Development and filling of materials with content, which has its own data warehouse, "Content" (see Fig. 6)

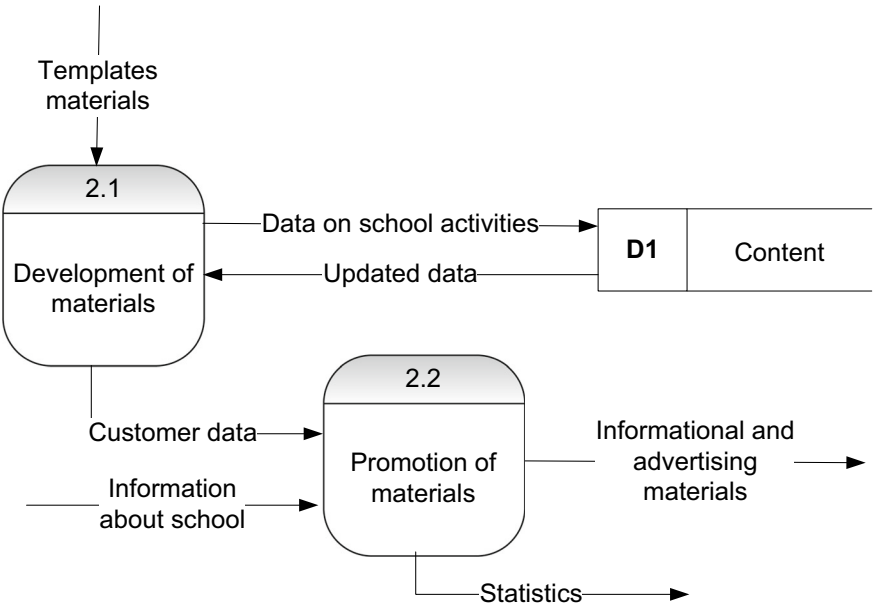

Fig. 6 The second level of decomposition of the diagram process "Development and filling of materials with content"

- Dissemination and analysis of statistics.

The process "Development of design of information and advertising materials" describes the procedure for creating the design of advertising products for schools. The process "Development and filling of materials with content" describes the procedure for creating content for the advertising printed materials of the secondary school and filling the materials with this information (Fig. 6).

The process "Dissemination and Analysis of Statistics" describes the procedure for disseminating the school's promotional materials and the analysis of the effectiveness of using these products to promote the school's services based on the study of statistical data.

The Materials Development process has input data flows—Materials Templates and School Information—and output data flows—Customer Data. The diagram also shows the "Content" data warehouse.

The "Promote Materials" process has two input data streams, "School Information" and "Customer Data," and two output data streams, "Promotional Materials" and "Statistics."

Thus, DFD diagrams represent data transformation functions in a system, including material objects and information.

To develop information and advertising materials for the school. Microsoft Office Publisher was used to develop informational and advertising materials for the secondary school. Microsoft introduced this product as one of the programs included in the Microsoft Office suite. Using Publisher 2021, we created a flyer, brochure, and business card. Microsoft Publisher is software that is part of the Microsoft Office suite. Microsoft Publisher is an editor designed to create all kinds of paper products needed for commercial activities, such as booklets, ads, forms, business cards, newspapers, and calendars. The advantages of Microsoft Publisher include a user-friendly menu, many built-in templates, a convenient system for formatting document sectors, a built-in drawing system, standards for all documents used today, and compatibility with other applications.

Microsoft Publisher integrates seamlessly with other Microsoft Office products like Word, Excel, and PowerPoint. This allows us to easily import and paste data and graphics from other programs and use standard fonts and formatting styles. Publisher is known for its ease of use, which makes it accessible to users of all experience levels. It has many built-in templates that make it easy to create various printed materials such as brochures, flyers, posters, and more. Publisher is well suited for creating print materials, including customizing pages, colors, and print resolution. It also has options for publishing to the web and exporting to other file formats. Publishers have rich graphics tools, including inserting and editing images, shapes, and drawings. Like other Microsoft Office products, Publisher allows users to collaborate on projects using cloud services and file-sharing capabilities. The Microsoft Publisher publishing system lets us quickly create standard publications based on templates: newspapers, brochures, calendars, catalogs, booklets, envelopes, business cards, invitations, greeting cards, menus, resumes, and product stickers. Microsoft Office Publisher 2021 is designed so that once the necessary marketing

material has been created and processed correctly, it can be emailed to any user, significantly simplifying the work. Microsoft Office Publisher 2021 has a feature that instantly prints the necessary materials. The program is designed to allow one to create and save marketing materials and send them or publish them. In addition to the additional printing function, Publisher 2021 can convert any file to XPS or PDF format, depending on the need. Opening the program will allow the use of multiple templates. Even if no standard templates are suitable, Publisher 2021 will quickly find and install any template we need using the search function.

The Publisher taskbar provides help for standard Microsoft Office Publisher 2021 procedures, such as inserting an image, merging standard sheets, or reusing content. Advanced catalog merging allows us to create frequently updated materials by combining text and images from a database, such as specifications, catalogs, and price lists. Advanced layout checker allows us to proactively detect and correct common layout errors in materials intended for printing.

When developing formal task models, we used MS Visio 2021, a diagram editor for Windows that uses vector graphics to create diagrams. It is available in two versions: standard and professional. The standard and professional versions use the same interface. However, the professional version has additional templates for more advanced diagrams and source formats and unique functionality to make it easier for the user to connect data from different source formats to be displayed in the diagram.

The easiest way to get started with Visio is to create a document based on a template. When loading a template, the Shapes task pane loads the categories of graphic elements that may need to create a diagram, plan, or map of the selected type. The main function of Visio is to visually represent existing data. Using external sources has its advantages. First, linking existing data to Visio chart elements is much easier than entering it manually. Secondly, when using external sources, updates can happen automatically—when we change an Excel file or other source, the Visio diagram data also changes.

Adobe Illustrator, a professional graphic editor, was used to develop the school's information, advertising materials, and logo. Illustrator works with vector graphics, which allows you to create scalable and clear images without losing quality. The program provides various tools for editing and manipulating objects, including paths, shapes, and text. Illustrator has powerful tools for working with text, including advanced formatting, effects, and manipulation of text objects. Integration with apps like Photoshop and InDesign makes it easy to move projects between different Adobe Creative Cloud apps. Illustrator has many tools for drawing, illustrating, and creating logos and layouts. The program supports importing and exporting various file formats, including A.I., EPS, SVG, PDF, etc. With Adobe Creative Cloud, we can collaborate and synchronize projects with cloud services.

In this section, the information and formal models of the problem of information and advertising support of the school were considered and created. A diagram of data flows was built, and the information content of the company was determined. For the practical realization of the task, it was decided to develop information and advertising materials for the school. As a technical solution, significant advantages are on the side of the MS Publisher 2021 software product, which is quite popular.

Creating advertising brochures and leaflets, newsletters, e-cards, business cards, etc., is possible.

This product's materials can be distributed in print and sent via the Internet by email. It meets all the requirements for software for creating advertising materials.

The fourth section describes the main informational and advertising materials for the school's products. After analyzing the company's needs and consultations with the school's management, the types of printing products to be developed were selected. These include the following: booklet, calendar in two versions, information sheet, form, and business card.

- Formation of textual material and graphic material.
- Development of product layouts: determination of page sizes, arrangement of text material on pages and related design parameters, etc.
- Production of an electronic product layout: layout, layout training, correction of specific errors.
- Production of a set of products necessary for printing the publication.
- Production and printing of products.

Having thoroughly analyzed the subject area, it was concluded that PR is the most effective means for the school. Is the production and distribution of printed materials.

Every sphere of human life, and especially education, requires competent advertising. Nevertheless, it is not enough to make an advertisement; the user must do it competently. Company advertising is a beautiful picture and an informative part. People should be attracted not only by slogans but also by informing potential clients about new services.

The corporate colors of the company's products are blue and yellow. Yellow symbolizes warmth, joy, and respect, while blue symbolizes loyalty, trust, and infinity. In other words, the company symbolizes respect and loyalty to its customers. The school's product logo is made in two colors—the school's corporate colors (Fig. 7).

A logo is created to attract the attention of others. The logo depicts the school's characteristic features, goals, and objectives—the partnership between students, parents, and teachers. The logo has become an essential tool in promoting and advertising the school—the importance of a school's logo. The school's graphic sign plays a vital role in creating its appearance. In particular, it performs the following functions:

- The logo is the school's graphic signature. It gives the school visibility and popularity. The logo should be placed on business cards and advertising posters as a trademark. In this case, consumers will get to know the school's services better.
- The logo gives the school a face. Using a logo makes it more successful, increasing its reputation in the eyes of others.

It is challenging to produce a high-quality image [33, 34] without having a logo. M.S. Office Publisher 2021 to develop promotional materials because users create a document based on a template, making the work much more manageable. Let us look at creating a brochure for the company. This process can be divided into several stages. The first stage is creating the topic and design of the work. The next stage is

Fig. 7 Logo of company products

selecting the primary information, including illustrations text. Furthermore, do not forget that all the material in the brochure should be easy to read, and if necessary, individual text and graphic elements should be grouped. The design stage includes the placement of the information on the brochure itself; it should be designed in a color scheme of several shades that are compatible in style with the main corporate colors of the school (Fig. 7). The most popular type of print advertising is the business card, a traditional carrier of basic information about a school. There are several types of business cards: personal, business, and corporate. Since we developed business cards for the company, the type of business cards used was corporate. It contains complete information about the school: the field of activity, list of services, contact numbers, website address, and email. It is designed according to the corporate identity. Usually, it has an advertising character. Business cards were created in Ukrainian when developing vertical business cards for the company.

One type of promotional product is a calendar; it can be a pocket, desk, or wall. Two types of calendars have been developed for school: a pocket calendar and a wall calendar with the days arranged by month. The calendar features the logo of the company, with the school's contact information below the logo.

Printed advertising includes catalogs, posters, leaflets, newsletters, commercial offers, flyers, booklets, brochures, catalogs, press releases, postcards, calendars, tablets, posters, brochures, business cards, and others.

Printed materials are business cards of an educational complex. It can be of both an informational and advertising nature. One of the main advantages of promotional printing is its relative cheapness and high information content, and it is also a great addition to advertising campaigns. Advertising printing products do not irritate the consumer, as they rarely interrupt the usual course of his life and are not imposed, unlike other media. One advantage of this advertising type is extended interaction time with potential consumers. In addition, such products (flip calendars, catalogs,

posters) presented to the consumer can attract the attention of a secondary audience. The main types of advertising printing are:

- booklet is a sheet printed on both sides with one or more folds that provides brief info about the school's services, designed for a mass audience;
- brochures-catalogs provide more complete information about the school's services, contain color photos, and detailed descriptions of services and prices;
- business cards are one of the most effective advertising media;
- business cards were developed, which included basic information about the school, its staff, and contacts. We also developed informational materials, such as class schedules and call schedules.
- pocket calendar is a universal and most popular branded souvenir that can be given both by itself and in a package with other promotional materials;
- quarterly calendar is a wall calendar that displays a quarterly calendar grid on the working surface. The convenience and functionality of quarterly calendars ensure their stable popularity among users, which is why they are most often used for corporate advertising;
- desk calendar is a business tool and a part of the desktop environment. A desk calendar is in front of a person's eyes all the time—the more memorable the advertising information placed on it will be, and it can also be made for one month at a time for the whole year;
- poster—a large advertising image.

Printed advertising in schools is distributed in various ways. It can be mailed, distributed directly at the school, or through other promotion methods, such as exhibitions and presentations. Advertising in an educational institution is a targeted dissemination of information about the school to inform the consumer, popularize the school's activities, and attract potential students and their parents. The purpose of advertising the secondary school is to communicate and bring information to customers. The task of advertising in education is to hide in the shadow of its means and techniques and push the educational product to the forefront so strongly that the advertising is not even noticeable. Today, advertising is the most effective and widely used means of influencing consumers in communication. The choice of informational and advertising material depends on the school's goal, financial capabilities, and creative advertising approach.

5 Conclusions

The role of advertising in modern society is complex and multifaceted. Initially, it was to inform consumers about a product, persuade them to buy it, and periodically remind them of it. Over time, the functions performed by advertising have expanded. Today, advertising in modern society plays many more roles, including economic, social, political, ideological, psychological, educational, and cultural. Printed advertising materials are developing in Ukraine in constant market transformation: periodicals

are gradually changing, especially their style and structure. Entering the competition, educational institutions must also advertise themselves through print advertising. Its precise organization allows the print media to succeed in the competition for customers and readers, so schools try to act in such a way as to ensure the maximum positive effect of their advertising activities. The effectiveness of the information and advertising activities of the departments with the help of print media directly depends on the successful content and its design. Printed materials were created to advertise the school. Corporate school advertising can solve many problems. This type of advertising, or "image" advertising, can be used to support activities that are considered socially useful, such as science, community service, charity, etc.

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The Pharmacist as a Businessman: Changing Market Situation

Bernhard Dietrich Koczian, Katarína Gubíniová, and Axel Sven Peisker

Abstract In the area of drug supply, the pharmacist is the recognised expert who reflexively checks the prescription of a treating doctor and, if necessary, intervenes in the prescription on a per-patient basis to avoid errors and complications. Pharmacists are also challenged as businesspeople and entrepreneurs but commercial and entrepreneurial skills are not among the core competences of pharmacy managers. The present research focuses on the perception of the dual function in order to determine whether pharmacists can fulfil both roles as pharmacists and entrepreneurs equally, or whether pharmacies are falling behind other competitors in the sector due to a one-sided core competence in the face of changing competitive situations and service requirements on the entrepreneurial side. With the core question "How is the task portfolio for pharmacists changing due to the internal and external requirement profiles?", a qualitative approach based on a key question interview with pharmacy managers is used to determine how they perceive their work and environmental situation, which role dominates in the tasks and which deficits and problem areas are recognised. The results of the analysis of the interviews show that task requirements in the entrepreneurial and business management areas in particular have a massive impact on pharmacies as companies. The main result recognised is that the training structure for pharmacists massively neglects entrepreneurial aspects and that the responsible managers do not have any valid and stable instruments or management concepts in their knowledge portfolio that structure tasks in marketing, personnel management or distribution.

Keywords Pharmacy · Entrepreneurship · Market changes

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1 Introduction

People suffering from various diseases frequently take medication, and their state of health is often jeopardised by side effects and interactions with other medications, either due to actual or potential problems with drug therapy (SVR 2023). Pharmacists, as experts in medication therapy, play a significant role in the areas of therapeutic management services that are built on a partnership between the pharmacist, the patient, the physician, and other members of the healthcare system on behalf of the patient [1]. Timely counselling helps patients to protect them from further, sometimes life-threatening, interactions or side effects so that they can achieve positive, targeted and efficient therapy outcomes. The framework for medication management is followed by the pharmacist through the treating physician's prescription in order to achieve desirable outcomes [2, 3]. At the same time, the pharmacist also fulfils another function in this medication management by acting as a controller of the prescribed medication and adjusting the medication in consultation with the attending physician if irregularities or interactions could occur. This keeps the quality of medication at the highest possible level in the interests of the patient/customer [4]. Pharmacists, through their positioning as retailers, become the most personally accessible members of the healthcare team. In addition, better coordination would be essential to monitor and ensure improvements in patient care, avoid duplication of services, reduce emergency department visits and hospital admissions, and help prevent the misuse of medications to reduce the risk of complications from drug therapy. In addition, follow-up costs that place an additional burden on the healthcare system can be avoided [5], (SVR 2023). All of these outcomes were considered effective and useful in achieving better therapeutic outcomes for patients and making the healthcare system more cost efficient.

The pharmaceutical industry has now grappled with major challenges such as uncertain market conditions for pharmacy, unstable pharmacy drug pricing, increasing competition, changes in regulatory requirements, the patent cliff, power shift from physicians to payers and patients, and patient empowerment in the growing era of the pharmaceutical industry. Therefore, every pharmacy large and small must also address these growing issues to maximise their value in terms of quality of products, cheaper medicines and public trust rather than volume. Manufacturers and health insurance companies have the power to influence this. The discount agreements between manufacturers and health insurance companies in particular channel the supply for the customer, so that the pharmacist can hardly exert any influence unless the medicine is not available. And the increase in supply bottlenecks has a strong influence on the marketability of pharmacies [6].

The training requirements for pharmacists are very strongly orientated towards pharmaceutical skills and are therefore highly scientific. This is necessary to a certain extent, but completely ignores the pharmacist's function as a freelancer and retailer. Practice-orientated approaches are taken during the one-year internship prior to graduation [7].

However, it should be noted that the trainers—also pharmacists without business and commercial training—have generally acquired the necessary knowledge as an additional qualification. Added to this is experience gained in professional practice. Nevertheless, many areas of the commercial side are carried out with the help of pharmaceutical commercial assistants, who have a qualitative advantage here. The pharmacist himself is always an adept and therefore trapped in a more passive role. Nevertheless, as a freelancer and owner, he must recognise and understand all issues and make decisions that serve the company and its employees. If the requirements are extended, the question arises as to whether a reorientation of the profession in training and studies should not be considered sensible in order to provide pharmacists with knowledge that allows them to perform management tasks better. However, given the rapid developments in the field of modern management, technologisation and digitalisation, the next generation of pharmacists will need to make fundamental changes during their studies in order to be able to meet these requirements [8]. According to the National Competency Standards Framework for pharmacists in Australia, there is a requirement to possess leadership and management skills, which begins with training during the pharmacy program [9]. However, if the conservative structures are left in place, the profession of pharmacist as a freelancer and retailer will become even less attractive and, as a result, fewer sales outlets will be established, which would accelerate the demise of pharmacies. The fact that this is already beginning to be recognised is shown by the falling numbers of graduates who are entering the profession of dispensing pharmacy or who are prepared to set up their own pharmacy. The shortage of specialised staff in pharmacies is the strongest indication here, which exists even with fewer sales outlets and relatively constant numbers of graduates. It is clear that the profession of pharmacist does not arouse much ambition among the younger generation [10].

2 Materials and Methods

Pharmacists occupy an important position in the healthcare system through knowledge transfer, counselling and supervisory functions. Pharmacists therefore have asymmetrical roles that make it difficult to fulfil their core competence of helping others when economic and political interests play a major role in defining their role. However, these partly new, partly existing and implicable tasks have forced pharmacists to develop new competences for themselves, some of which take them away from their existing core competences. The key question is: “How is the portfolio of tasks for pharmacists changing as a result of the internal and external requirement profiles?” This leads to the question of which knowledge management must be provided and which management tools can be utilised in order to effectively implement all these tasks in the interests of the customer.

The fact is that Pharmacists are increasingly forced to take on competences that lie outside their core competences, to take on implications of new tasks and changed processes that make work in the core area more difficult. The following hypothesis

is formulated: It can be assumed that traditionally orientated individual pharmacies in particular will not be able to cope with the transformation requirements from their own perspective and will therefore leave the market in the foreseeable future. This would have an impact on the drug supply sector and would have a negative effect on parts of the healthcare system. By defining the role model for pharmacists, the research work makes recommendations based on the results obtained, which must be based on a new foundation for the pharmacist job profile. Areas are primarily to be seen in the areas of training and studies.

A qualitative approach based on a key question interview with pharmacy managers is used to determine how they perceive their work and environmental situation, which role dominates in the tasks and which deficits and problem areas are recognised. The current study was conducted to examine the mission of the pharmacy and the perceived role of the pharmacist in the changing environment of the public health system and the economic and technological changes.

The selection of test subjects for the research presented here is straightforward, as the focus was set on the fixed reference group of pharmacy owners as managers. This fixed selection of test subjects also facilitated the choice of qualitative research using narrative interviews, as the sociologically defined situation is exclusively reflected within this group.

The selection of the pharmacists surveyed here was not based on specific criteria, such as pharmacy size, time of existence or similar, but was based solely on the professional profile and thus on membership of the defined test group according to one criterion.

In the current study, the qualitative research method with a guiding questionnaire-based survey technique is used to interpret and address the research problem and achieve the desired research objectives [11]. Qualitative research was used in the current study to explore the changes in pharmacy and the current perceptual role of the pharmacist with increasing responsibility in the healthcare system. Over the years, the use of qualitative research in the healthcare sector has increased to apply methods specifically designed to analyse and explain both patients and the thoughts of professionals in the helping professions [12].

Qualitative research is also favoured in the current study to democratise the research methods so that the research can be inclusive, collaborative and participatory due to the growing partnership and co-production of pharmaceutical practices under changing market conditions. Qualitative research, which is favoured in this study, has provided a framework for research that is not just with or about the participants, but rather with or by the participants as co-creators [13]. The conceptual background to this approach lies in the fact that the examination of a topic that can still be described as largely unexplored initially requires a data basis that is not based solely on figures, as it excludes different patterns of experience and opinion in depth, but rather deals with a group of the main actors, in this case the pharmacy managers. Particularly when it comes to the question of role perception, it is important not to operate with columns of figures, but to record the roles in their individual form and to determine them on the basis of an equally individual reflection with more in-depth justification.

Qualitative research methods are based on the hypotheses of self-gathered experience within a specific research area. The qualitative research method for the current study utilised a sample using interviews with a focus group survey. The qualitative research method was preferred because it is considered very useful for conducting a behavioural and perceptual analysis through semi-open-ended questions. In the present form, the questionnaire is set up with semi-open questions, which allow the respondents to focus more strongly on the research questions. By obtaining the opinions of the survey participants on the role of the pharmacist in the changing business environment of the pharmacy, it is primarily self- reflective experiences of the respondents that are queried.

The question structure set up here is based on the dominant leading question, but auxiliary topics are also explained, which allow the interviewer to clarify the question in case of incomprehension on the one hand, and to have a prepared portfolio of expected further contexts that can clarify the answers on the other. "The interviewer can help the interviewee with additional information and follow-up questions and motivate them to give better and more complete answers." [14]

Own perception of the pharmacy sector in an expanded field of competition from online offerings, drugstores and discounters. **Key question**: "How do you see the current positioning of pharmacies against the background of the existing market situation and framework conditions?" Focusing on the question without centring too many references on the pandemic situation. The political purpose of the profession also resonates in the background. Auxiliary topics: Competition in own sector; international competition; online providers; drugstores and discounters; legal restrictions on the profession perception of one's own role as an inpatient pharmacy in the healthcare system, as a starting point for in-depth study.

Key question: "Has the role of inpatient pharmacies in the German healthcare system changed in the last 30 years? If so, how?" Auxiliary topics: Task extensions; New fields of work; Other customer expectations, concretisation of the role perception in one's own company.

Key question: "Where do you currently see your main tasks as a pharmacy manager?" Auxiliary topics: More administration; More management; Less advice; More business customer advice in the form of authorities, doctors and businesses as on-site advice for customers. 4 New areas of responsibility must be identified.

Key question: "In your opinion, where have new areas of responsibility emerged and which existing tasks need to be restructured/reorganised?" Auxiliary topics: Specialisation in one or a few additional areas; more business orientation towards facilities; own online offer; e.g. services no longer (as before) as a free matter of course, but paid for by the health insurance funds as a legally fixed standard service new tasks require either personal initiative, new employees or the involvement of existing employees.

Key question: "Have you personally taken on new management tasks or have employees been given responsibility for new areas of work?" Auxiliary topics: Multiple tasks, such as recruitment, retention and training; logistics and distribution; new hierarchy: tasks given to employees with more personal responsibility (delegated tasks). The question of organisation, structure and planning arises with new tasks

and entire fields of activity. There are numerous business management functions in all areas. However, it must be scrutinised whether a sub-specialist (pharmacist as businessman) resorts to these or only acts intuitively.

Key question: "What measures have you used to implement and realise new areas of responsibility (e g. personnel, distribution, logistics, etc.)?" Auxiliary topics: Talent pool; candidate expectations (candidate experience); lean management; Six Sigma etc. The test persons do not have to know it (also counts as a result!).

New tasks in structures that affect the entire company may be a case for outsourcing to a specialist. For example, IT tasks, special medical services or recruitment can be outsourced to external partners. Alternatively, these partners can provide further education and training. **Key question**: "Have you utilised external partners as service providers or their knowledge potential in your own training courses when converting and changing tasks or areas of responsibility?" Auxiliary topics: Personnel management; logistics and distribution service providers; specialists in a specific health area (nutritional counselling, cosmetics, sports medicine, etc.).

Every change can bring problems and present a company with challenges. These problems are important for self-perception and role perception. **Key question**: "What changes in the framework conditions have made or will make adjustments necessary for small businesses (e g. bricks-and-mortar pharmacies) and what do you see as the main problems?" Auxiliary topics: Procurement of knowledge and information; in-house design; increasing use of external services in knowledge-intensive areas; tasks that deviate greatly from core competences. The current pandemic situation has an impact on all sectors. Pharmacies are an important part of the public healthcare system. **Key question**: "Has CoVid-19 changed the pharmacy industry and your own business last year and into this year?" Auxiliary topics: Change in demand; more online purchases; counselling services, perception of pharmacies by customers, politics; offering new services (e.g. testing).

The possibility of summarising self-perception. Such forms of interview always create an in-depth consideration of one's own position and perception of the environment. Many interviewees discover new perspectives on their situation through such conversations and re-evaluate it as a result. **Key question**: "When you summarise and concretise your role, which predominates? That of the pharmacist or the manager?"

The possibility of a prospective outlook on one's own situation and that of the entire pharmacy landscape. **Key question**: "If you look 5–10 years into the future: What do you think the future of your pharmacy and the German pharmacy landscape could look like?" Auxiliary topics: Effects of a possible political change; Longer-term structural effects of the Covid pandemic on the purchasing behaviour of society; Political foundation of pharmaceutical services as a paid service Vaccination lines.

3 Results and Discussion

To analyse the results, the test subjects are differentiated according to certain characteristics that are relevant to the research questions and the hypotheses. For further assured anonymisation of the test subjects, the age is determined in a 'from to' frame and the business location is defined as a large city > 100,000 inhabitants, medium-sized town 20,000–99,999, small town < 20,000 and rural town < 5000. The number of pharmacies does not need to be artificially alienated. The list of respondents represents Table 1.

"**It is assumed that the core competences of pharmacists will continue to be highly relevant in the healthcare system and for customers**."

This hypothesis can only be confirmed to a limited extent, as the core competence of dispensing medication is becoming less and less important. At the same time, expertise in counselling and knowledge of pharmaceutical issues and interrelationships in terms of healthcare services is increasing. As a result, other providers who are not part of the 'community pharmacy' market segment are increasingly accounting for part of the total volume of medication supply. However, a high proportion remains in the provision of quality advice to customers, which cannot be provided by alternative providers in this form. Looking to the future, the respondents assume that this shift in core competences will extend to advisory functions and that pharmacies will be increasingly located in healthcare networks as their numbers decrease.

When applying the core competence of pharmacist, it is primarily the older respondents who still see themselves more strongly in this role, while younger pharmacists either increasingly concentrate on the tasks of pharmacy manager or harmonise both roles equally. The tendency to be forced to take on managerial roles was emphasised more often than voluntary acceptance, as this is what the majority of the personnel situation demands.

"**It is assumed that pharmacists evaluate new tasks and processes differently depending on the business structure (individual pharmacy/branch pharmacy)**."

Table 1 Subject parameters age/number of pharmacies owned/location of pharmacy

	Age	Number of pharmacy	Place of business
Respondent A	60+	1 pharmacy	Big city
Respondent B	50–60	2 pharmacies	Middle town
Respondent C	30–40	1 pharmacy	Middle town
Respondent D	40–50	1 pharmacy	Big city
Respondent E	30–40	1 pharmacy	Big city
Respondent F	40–50	2 pharmacies	Small town
Respondent G	60+	1 pharmacy	Big city
Respondent H	40–50	1 pharmacy	Middle town
Test person I	50–60	2 pharmacies	Big city

Source Own presentation 2023

This hypothesis can be confirmed based on the results of the analyses of the interviews. Individual pharmacies are more positive about accepting new tasks in the area of healthcare services than pharmacies with a branch structure. For the individual pharmacy, taking on more counselling and extended tasks in the health sector of prevention and support measures for customers means a supplementary income model to the declining sales of medicines, on which pharmacies mainly live economically. To this end, the actual core competences of the workforce can be better utilised than would be the case in areas that move away from the core competences. However, it would be important to utilise digital possibilities and communication channels in the interests of customers, which could be achieved with simple means. In the interviews, however, the respondents recognised that the potential here is only insufficiently exploited, which on the one hand is linked to the possibilities of technical renewal through investment, which is only possible to a limited extent through turnover. On the other hand, measures in these areas are always dependent on personnel, so that there is status quo coverage due to the shortage, but expansions do not seem possible.

This would be particularly true when setting up, using and maintaining a web shop, which places greater demands on both employees and the manager. Data protection is one of the most sensitive factors here, with the highest risk factors in the compliance requirements. Added to this are staff deployment and working hours, which could only be efficiently implemented by new staff.

In their statements, the test subjects made it clear that the costs were considered too high and that the benefits were only marginal compared to fully established competitors.

In the case of branch pharmacies, there is also the fact that generally new healthcare services in several pharmacies also require an even greater investment of capital and staff, which is difficult to fulfil with existing staffing difficulties. For this reason, one in three of the test subjects is also rather negative, as customers are slow to accept new offers in pharmacies that they may have received in other healthcare areas. An example of this is immunisation, which is mostly carried out by doctors, even though new options are available. There are also investment requirements that are difficult for all pharmacies to implement. Changes in room utilisation or new requirements for rooms for the use of services can either not be met (no capital or no permission to change rooms due to legal requirements) or are not possible due to a lack of staff, which can be used for this by restructuring the tasks without having to accept massive losses in the core tasks.

"**Pharmacists are increasingly forced to take on competences that lie outside their core competences, to take on new tasks and changed processes that make their work in the core area more difficult**."

This hypothesis is also clearly confirmed by the qualitative survey of a small sample, as all test subjects either stated that they did not work with new management concepts or that they were unable to apply them because they were unfamiliar with them and had never learnt them during their training or later in their active careers. Although the younger respondents are familiar with the concepts, they are not used as a structured management function because their knowledge is insufficient. Here,

increasing demands are being placed on the profession and the position as businesspeople, but these cannot be met, as the active core competences make great demands on the test subjects. In addition, there do not appear to be any special offers in the form of further education and training, as these are not sufficient to utilise all aspects efficiently.

It is not possible to demand that pharmacists provide more technical and business services and acquire more knowledge simply because pharmacies are freelance businesses. Due to the strict requirements that the state places on pharmacists, these are only possible to a limited extent or simply not at all if the legal mandate is to be maintained. The fact is that pharmacists are not IT specialists, they have not studied business administration and are unable to carry out marketing or personnel management like other companies with specialists. Many things—the statements of the test subjects clearly confirm this—are decided on the basis of 'gut instinct'. Intuition is the factor on which decisions are based. Knowledge here remains based on experience and not on sound knowledge management, which pharmacists would have to acquire in addition to their specialist pharmaceutical knowledge.

The discussion on this will be taken up more intensively, as this is also a future-oriented aspect that should be included in the organisation of training and studies if pharmacies are to be broadly positioned in competition. Younger pharmacists between the ages of 30 and 50 at the most could still do their own work here in order to position themselves more securely for the future. Above that, however, the demands are different and the focus is more on the last active phase of work and how to fulfil it in a stable manner. This is not to be confused with fatalism but is based on the willingness to see how much new work still needs to be done in order to improve one's own performance as a pharmacy manager. As the results show that the older test subjects concentrate on their role as pharmacists, there is little ambition here to perform even more themselves, but to delegate tasks.

"**It can be assumed that traditionally orientated individual pharmacies in particular will not be able to cope with the transformation requirements from their own perspective and will therefore leave the market in the foreseeable future**."

This hypothesis cannot be confirmed by the test subjects in all of the points mentioned. For example, the subjects with individual pharmacies described the customer structures as regular customers, which means limited access to new customers. These pharmacies are often passed on generatively and have fixed structures that are difficult to break up. This affects both the feasibility and the attitude of pharmacy managers, most of whom started their careers as pharmacists and now need new skills that they do not have in their existing knowledge portfolio. An expansion of the customer radius via online solutions is only realised to a limited extent or not at all due to the feasibility and the expected low benefit.

On the other hand, the new healthcare services are a positive factor that can be expected to stabilise or increase sales, elevating pharmacies to a new form of healthcare provider. However, the respondents also emphasised that the existence of pharmacies depends on the medical infrastructure in the catchment area. Like pharmacies, this is increasingly declining or is concentrated in group practices or

medical care centres, so that much will depend on whether centralised regional healthcare networks develop in which pharmacies can participate. This is particularly crucial in suburban and rural regions, which have a fragmented population structure and are therefore reliant on customers who are prepared to travel further. Solutions to distance as a barrier can therefore only be found through technical solutions if digitalised communication structures are in place and, on this basis, the quality of the pharmacy's service to customers is maintained. Although community pharmacies already offer comprehensive courier services, as customers now perceive this as a standard service, these are more cost-intensive and time-consuming for pharmacies to plan.

Whether more individual pharmacies with the usual core competences will disappear from the market or more branches will be closed because they are no longer viable in terms of staffing and investment requirements cannot be definitively determined at this time. The fact is that rural pharmacies in particular are increasingly closing without replacement, but the first branch pharmacies have also been taken off the market since 2022. If we look at the statistical development of pharmacies in terms of branching, takeovers by successors and the high average age of pharmacy managers, more than 300 pharmacies on average will disappear from the market in around ten years as a result of pharmacies closing for reasons of age and insufficient demand for pharmacies from younger successors during this period. This also requires a political rethink in terms of the demands placed on the profession and its safeguarding. To this end, more incentives need to be offered to make it appear positive for generations Y and Z to take over or open a new pharmacy.

On the basis of the findings of this research, it can be stated that the findings from qualitative research make a valuable and expanding contribution to the knowledge base of the relevant professional groups in the healthcare sector. Extended research is required. Previous approaches have favoured quantitative approaches, as they are easier to design, cheaper and quicker to analyse. However, pure databases can often only be seen as an insight into existing problems, but they rarely offer causes and reasons for how the problems are taken up and dealt with. Larger-scale research would therefore be highly recommended here in order to have the greatest possible validity, which would also allow generally valid results to be extracted from the analyses for the relevant group in each case.

4 Conclusions

Occupational fields in the healthcare sector occupy a special position, as the work of the employees is already strongly determined by intrinsic motivations in that helping is at the centre of the activity. Pharmacists are also to be found in such an occupational field, as they occupy an important position in the healthcare system through knowledge transfer, counselling and supervisory functions.

Pharmacists therefore have asymmetrical roles that make it difficult to fulfil their core competence of helping others when economic and political interests play a major role in defining their role.

It was recognised in the interviews in our own research that this dual role cannot be performed without problems, as the responsibilities towards the staff lie in the economic functionality, while the helping aspects can no longer be fully assumed. Although this is not based on altruism, the helping aspects are closely linked in the career choice. As a result, economic aspects that are actually necessary are assumed; they are not subject to the same system as the core pharmaceutical profession. In order to provide equivalent services in both areas, integrated training and study programmes covering both areas would actually be required. However, the core pharmacy professions for the pharmacy segment are geared towards high quality in pharmaceutical matters and therefore only offer an economic livelihood for all pharmacies as long as the profession is protected. Since 2004, this has no longer been the case due to liberalisation efforts at European level. Companies whose core competences lie in the commercial sector and are also strong investors are putting pressure on pharmacy managers, who are highly self-taught, and are increasingly forcing them out of the market. Nevertheless, a legal mandate is required that restricts pharmacists in their freedom of action, while the new companies are exempt from this in many areas.

If the pharmacy market is to continue to fulfil this legal mandate, then the state must offer pharmacists and employees the opportunity to face up to the competition in terms of quality, including in the economic area. Fundamental considerations must therefore be made as to how the future organisation of the pharmacy profession should develop. First and foremost, there are opportunities to expand financially, which require higher remuneration. In addition, the entire training pathway must become more dual and develop into a separate degree programme geared towards pharmacist activities, in which future self-employment is pre-programmed in many cases.

The most important prerequisite for a sustainable improvement in the economic situation of public pharmacies in Germany is their adequate remuneration for the tasks assigned to them by the legislator. As this remuneration has been decoupled from the overall economic development since 2013, the gap between the permanently rising and uncontrollable costs (e g. inflation, energy costs, rising standard salaries, fees passed on to pharmacies by manufacturers, wholesalers, banks, increased credit and loan interest rates, etc.), which pharmacies cannot pass on or charge on, and the politically even lowered remuneration for the dispensing of prescription medicines and medical devices, is widening.

The necessary personnel, technological innovations and the purchase of external expertise are only possible if the necessary capital is available.

Findings for the pharmacy sector, such as staff shortages, declining sales and the disappearance of more and more pharmacies without replacement for customers, are findings that can be easily substantiated with statistics. However, there is no consideration of personal opinions and statements on how to deal with these problem areas. Findings that can be drawn from the small scale show that pharmacists as owners and pharmacists repeatedly fail in their profession, particularly in the area of commercial and business management requirements, or show the greatest problems in coping with them.

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From Connectivity to Security: Ensuring Cyber Resilience in Socio-technical Systems with Social Networking Services

Vadym Kolesnyk, Kateryna Molodetska, and Solomiia Fedushko

Abstract This article examines socio-technical systems, with social networking services being highlighted as a specific example of these systems. Socio-technical systems integrate social and technical elements to achieve common goals, combining components such as people, technology, infrastructure, culture, processes, and objectives into a coherent whole. Social networking services play a pivotal role in enhancing communication, collaboration, and information exchange, and this paper delves into the synergy created by integrating socio-technical system with social networking services. The concept of phygital solutions, which blend physical and digital experiences, is examined, stressing its significant and practical relevance in modern socio-technical system. Cybersecurity's role in safeguarding socio-technical system from various threats and strategies to ensure robust security are also discussed. The processes within socio-technical system, including communication, information management, automation, project management, and personnel development, are analyzed to understand their impact on efficiency and effectiveness. The paper concludes with insights into the future development of socio-technical system and social networking services, addressing challenges such as integration, data management, and ethical considerations, and emphasizing the importance of continuous innovation and adaptation. This comprehensive analysis underscores the essential nature of socio-technical systems in the digital age, providing a framework for future research and practical applications.

Keywords Socio-technical systems · Social networking services · Cyber resilience · Phygitality · Cybersecurity · Vulnerabilities · Information management

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1 Introduction

In today's world, where technologies are constantly evolving, understanding and managing socio-technical systems is becoming critically important for the successful functioning of various organizations and societies. Socio-technical systems are an example of complex systems, specifically technological and social systems that interact to achieve certain goals. These systems include technical tools and infrastructure and people, their roles, processes, and organizational structures. Social networking services have become integral to many people's daily lives. They include social networks, blogs, forums, platforms for sharing multimedia content, and other tools that facilitate communication and collaboration in an online environment. Thanks to social networking services, users can quickly exchange information, organize joint projects, and build social connections, significantly changing the way people and organizations interact.

Socio-technical systems can be found virtually everywhere today. The creation of the Internet has greatly expanded the possible applications and types of socio-technical systems. Social Networking Services are a partial case. Facebook, X (Twitter), LinkedIn, Reddit, Instagram, TikTok, and others are examples of social networking services actively developing and attracting more users. Social networking services popularity is increasing due to the continuous improvement of functional characteristics and integration between different services for content synchronization [1]. Social networking services play a significant role in bringing together individuals and organizations. They serve as platforms for communication, idea exchange, and community building [2].

Socio-technical systems are an important aspect of modern society where technologies and social components interact to achieve common goals. Viewing a socio-technical system as a unified system allows for a deeper understanding of the complex interactions between people, processes, and technologies. Technological advancements in recent decades have significantly changed how we organize work, education, and leisure, creating new opportunities for collaboration and communication. At the same time, these changes require considering social aspects such as culture, education, and social connections, which are integral to the successful functioning of socio-technical systems.

In today's world, where social networks have become an essential part of everyday life, it is important to understand their role in the context of socio-technical systems. Social networks such as Facebook, Instagram, and Twitter allow people to exchange information, build social connections, and organize joint projects. They foster the development of new forms of communication and collaboration, significantly influencing social, political, and economic processes. Videos ranging from two to five minutes in length are regaining popularity as social platforms increase the maximum video duration. For instance, Instagram allows users to post videos that are up to 15 min long, while TikTok is experimenting with similar features [3]. More users are engaging with brands through direct messages (DM). This trend has become particularly evident on platforms like Instagram, where new features such as "Notes" and

"Broadcast channels" encourage this type of interaction [3, 4]. Social networks have become essential tools, influencing society's economic, social, and political aspects by enabling users worldwide to connect, share interests, and exchange information. However, the rise of digital communities within social networks also brings challenges, particularly regarding the spread of harmful content, user conflicts, and information security risks [5, 6]. Virtual communities are classified based on various characteristics such as content access (open or closed), content structure (semi-structured or unstructured), stability (temporary, medium, stable), size (large, medium, small), and content type (socio-ethnic, socio-demographic, socio-professional) [2]. These communities can be academic, educational, informational, multimedia, professional, or communication-focused [1, 2].

One of the important aspects of studying socio-technical systems is their ability to adapt to changes. This includes both technical innovations and social changes. For example, the development of Internet of Things (IoT) technologies, augmented reality (AR), and virtual reality (VR) creates new opportunities for integrating physical and digital elements into a single system. Such phygital solutions allow users to interact with real objects through digital interfaces, improving user experience and system efficiency. The integration of physical and digital elements in phygital solutions allows for the creation of new forms of interaction and enhances system efficiency. This includes using augmented and VR technologies [7], the IoT [8], and other innovative solutions that improve user experience and achieve new productivity levels. However, such integrations also require consideration of security and privacy issues to protect data and ensure system reliability.

New technologies are continually employed in social networking services to attract new users and retain existing ones [3, 9–11]. The rise of digitalization and phygital experiences has led to the adaptation of marketing strategies, with companies increasingly using social networking services as a primary tool in their campaigns [3, 4]. Cybersecurity is another crucial aspect of socio-technical systems. As dependence on technology grows, so does the risk of cyber threats that can negatively impact system functionality. Ensuring reliable cybersecurity requires developing strategies to protect against various threats, including data protection, access management, and system activity monitoring. Cybersecurity has become paramount for these systems in the contemporary landscape, emerging as a top priority. The increasing frequency and sophistication of cyber-attacks make it imperative to implement robust security measures to safeguard information and maintain the integrity of socio-technical systems. High-profile breaches and data leaks have underscored the devastating potential of cyber threats, causing financial losses, damaging reputations, and undermining user trust. The interconnected nature of modern socio-technical systems means that a single vulnerability can have cascading effects, disrupting entire networks and critical infrastructures. Therefore, prioritizing cybersecurity is not just a technical necessity but a strategic imperative to ensure resilience and reliability in the face of evolving digital threats. Threats to information security in SIS can lead to chaotic dynamics of actors' interactions, potentially transitioning from online environments to real life, causing protests and unrest [1].

Social networks are also used as tools in hybrid warfare, combining political, economic, military, and informational means to achieve strategic goals [6]. It is important to develop critical thinking and media literacy among users to protect against manipulation and misinformation [5]. Additionally, antagonistic behaviors in online communities, such as trolling, flaming, and cyberbullying, negatively impact the health and well-being of these communities [5, 6, 12]. Implementing moderation policies and reporting systems is crucial to mitigate these adverse effects [6].

Social networking services are a vivid example of socio-technical systems. They combine technical platforms and social interactions, creating an integrated communication, collaboration, and information exchange environment. Social networking services significantly impact organizations and society, fostering the development of new forms of social interaction and business models. For example, companies use social networks for marketing, customer engagement, and brand building. This creates new opportunities and challenges that require careful analysis and a strategic approach.

The primary issue lies in the insufficient integration of theoretical models with the practical needs of users and organizations, leading to inefficient implementation and utilization of these systems. The lack of robust cybersecurity strategies [13, 14] exposes the systems to the risk of attacks, resulting in significant financial losses and a loss of user trust.

This study aims to conduct a comprehensive analysis of the functioning of socio-technical systems and identify strategies for ensuring the cyber resilience of these systems by examining how technical innovations and social changes can be harmoniously integrated to enhance productivity and security. Additionally, this study aims to analyze the role of phygital solutions in improving interactions between users and technologies in the context of cybersecurity.

2 Socio-technical Systems

Socio-technical systems result from the evolutionary synergy between social and technical systems. They are complex, possessing emergent properties from their predecessors, and operate to achieve common goals. Socio-technical systems are systems in which human beings and technological elements created by human beings participate [15]. Socio-technical systems have six main components.

In Fig. 1, the main components are depicted, with all elements interacting with each other to varying degrees and for different purposes. The social segment consists of actors and culture. The technical segment comprises technology and infrastructure. They are united by processes that occur at all system levels, but the main interaction transpires between actors, technologies, and processes, as well as the shared goal of the system's activities. Socio-technical systems have properties inherent in both social and technical systems. Emergence occurs when two or more systems synergize into a higher-level complex system. Emphasizes the need for a balanced approach to designing organizational systems that consider human and technical components

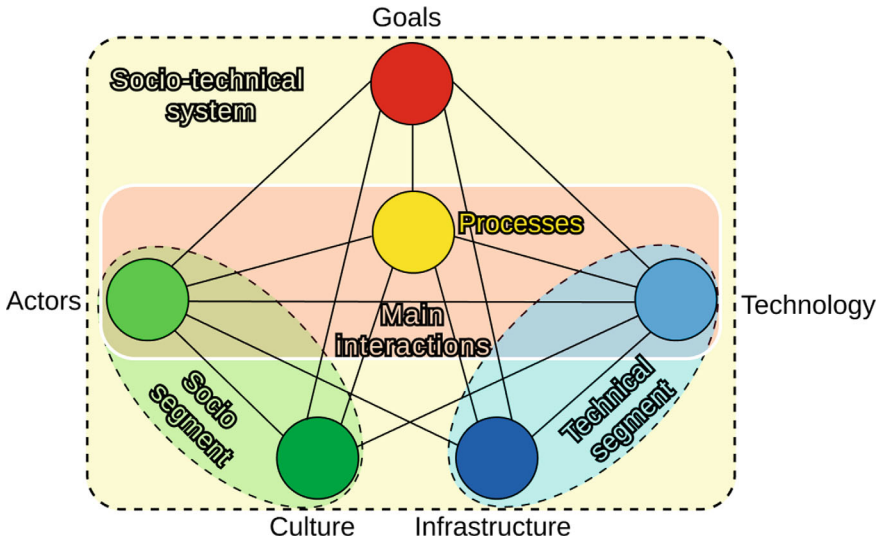

Fig. 1 Components of socio-technical systems

[16]. New properties and structures arise in the system through the interactions between its components, which cannot be predicted solely based on the properties of individual components.

The new approach to decision-making amidst antagonistic user behavior emphasizes the decision-making process in stable online communities [17]. Integrating these approaches within socio-technical systems underscores the need for robust management strategies to navigate the complexities of digital interactions and information security. The findings demonstrate that effective decision-making processes can transform online communities into resilient socio-technical systems capable of thriving amidst antagonistic digital communication environments [12, 18].

The interactions within a system lead to new properties that are not present in the individual components [19]. Emergence in socio-technical systems is a key aspect that determines how the interaction between people and technologies leads to the emergence of new properties and behaviors of the system. The process of emergence in socio-technical systems involves mechanisms of self-organization, interdependence, and unpredictability. This means that individuals and groups autonomously organize around common goals, using technologies as tools, and changes in one part of the system affect others. Examples of such emergence are the Internet and social networks, where platforms create new forms of social interaction and communication. This can lead to the rapid spread of viral content, the organization of social movements, and changes in business models. In the context of organizations and enterprises, emergence is manifested through adopting new technologies and implementing innovative processes, such as Agile methodologies and ERP systems, which enhance efficiency and create new forms of organizing work processes.

Emergence in socio-technical systems is also accompanied by challenges. One of these is unpredictability, which complicates the prediction of how component interactions will lead to new properties. This creates difficulties in managing such systems, as new properties may pose risks to security and privacy. At the same time, understanding emergence opens up prospects for innovation, increased efficiency, and the development of management methods that enhance systems' resilience and adaptability.

Cyber resilience is defined as the ability of these systems to anticipate, withstand, recover from, and adapt to adverse cyber events. This capacity is increasingly vital as the proliferation of social networking services in society continues to rise, thereby necessitating robust cyber resilience frameworks within these systems. Socio-technical systems and social networking services are especially vulnerable to cyber threats due to the extensive interactions between human actors and technological components. These interactions often generate numerous entry points, thereby heightening susceptibility to cyberattacks [20]. The escalating frequency and sophistication of cyber threats necessitate advanced protective measures to address the rising incidences of data breaches, unauthorized access, and system disruptions.

2.1 Socio Segment

Actors. At the core of the socio part of the system are two elements: actors and culture. Actors are the system's driving force, performing various roles such as users, operators, managers, and developers. The interaction of actors with the technical components of the system through interfaces, decision-making, system adaptation to their needs, and setting system goals is key to their work. Actors in social networking services form a complex, nonlinear, dynamic system that interacts with national and global information spaces [1]. Their communication is characterized by openness, nonlinearity, disequilibrium, and dissipation [1, 6]. Connections between actors in social systems arise chaotically in real life and virtual communities (Fig. 2). Each actor has a role and influences the system through their actions, decisions, and interactions with other actors and technical components.

In the context of social networking services, examples of actors include users, developers, and administrators (Table 1). Users interact with the service by creating content, commenting on and sharing posts, searching for information, and exchanging posts. Developers are responsible for creating and improving the software for social networking services, but they are also actors who influence the system's functionality. Administrators are specialists who monitor compliance with platform rules and data protection.

Each actor may perceive the goal of the socio-technical system differently, or under the influence of culture, a common understanding of the goal may begin to form.

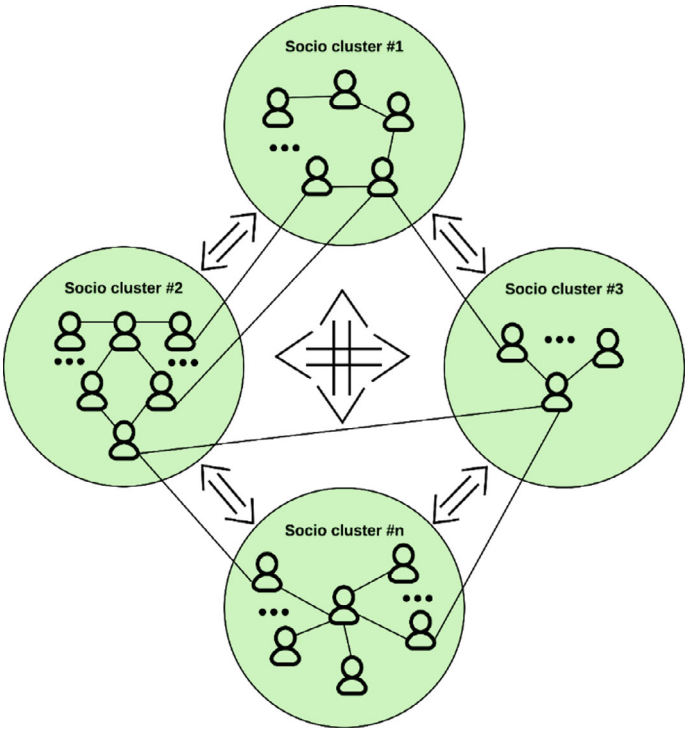

Fig. 2 Connections between actors

Table 1 Example of actors' roles in social networking services

Role	Description	Role in cybersecurity
Users	Individuals who interact with the service by creating content, commenting, sharing posts, searching for, and exchanging information	Must adhere to security rules, avoid sharing confidential information, and be cautious of suspicious messages and links
Administrators	Specialists who monitor compliance with platform rules and data protection	Monitor and manage system security, detect and prevent cyber threats, and ensure compliance with regulatory requirements
Developers	Responsible for creating and improving the software for social networking services and influencing the system's functionality	Ensure the protection of user data, implement security mechanisms, and promptly fix vulnerabilities

Culture. The organization's culture, the community of actors using the socio-technical systems, defines the norms of behavior, values, expectations, and attitudes towards technology. Culture influences the efficiency and acceptance of the system, as it determines how willingly the system's participants will interact with the technologies and processes. Culture also includes the education level of the actors within the system, their relationships with other actors within a particular community, circles of interest, certain organizations, etc.

The values of actors regarding certain norms are the basic principles and standards that determine acceptable behavior and influence actors' decisions. These include ethical standards, professional codes, social norms, individual or collective ideas, interests, and social circles. In social networking services, values include respecting user data privacy, transparency in software development, ethical use of technology, gathering actors around common ideas, and providing tools for expressing and sharing opinions, ideas, and interests.

The education level, professional training, and experience of the actors determine their ability to understand and use technical innovations and make informed decisions. Personal and group motives that drive actors to action include economic benefits, social status, personal beliefs, and other factors. The ways and means through which actors interact with each other and the system's technical components are also crucial, including both formal and informal communication networks.

The socio-segment represents a social system. All actors have connections of varying lengths and weights within the system.

Each element of the social system is an individual who can have connections with other elements, create new ones, and lose old ones (Fig. 3). Culture directly influences each element of the system and its overall state. The social segment is dynamic and interconnected. Actors and culture continuously influence each other, creating a complex interaction network that impacts the entire system. New technical solutions can change the culture of the social segment of the socio-technical system, while cultural changes can encourage the implementation of new technologies or changes in technical processes.

The social segment is also an open system that interacts with the external environment, accepting and adapting to external influences. The interaction between the social and technical segments of the system ensures the adaptability and resilience of socio-technical systems, making them capable of innovation and development in the face of constant change.

The socio-segment of socio-technical systems encompasses the human and cultural aspects that interact with technological components to achieve system goals. Cyber resilience within this segment is crucial, as human factors and cultural influences significantly impact the system's overall security posture and ability to withstand and recover from cyber incidents. By fostering a culture of security awareness, encouraging collaboration, and preparing individuals to respond effectively to incidents, organizations can enhance their overall resilience to cyber threats. This holistic approach ensures that the socio-segment supports and actively contributes to the robust cyber resilience of the entire socio-technical system.

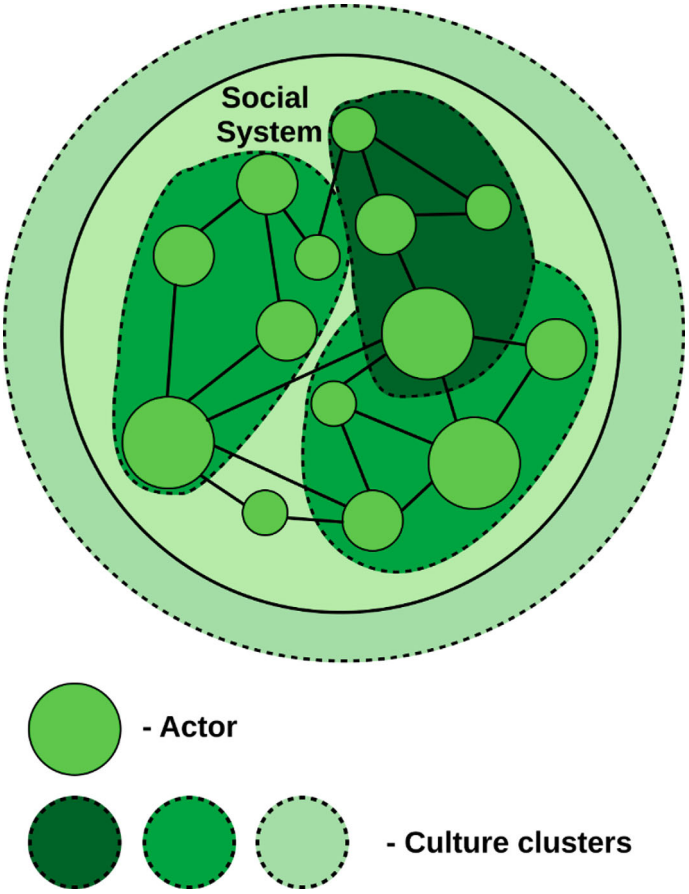

Fig. 3 Typical example of social system

2.2 Technical Segment

Technology. Technology includes various services, software products, algorithms, processes, and methods for automation, analysis, data processing, and other tasks. Technology provides the system's functionality and allows actors to interact effectively. In social networking services, technologies include software, websites, platforms, databases, various analytical tools, artificial intelligence, robotic systems, and more. Platforms like Facebook, X (Twitter), or LinkedIn use complex algorithms to analyze user behavior, personalize content, and manage user interactions.

The technical segment of socio-technical systems encompasses the technological infrastructure, tools, and processes that support the system's functionality and objectives. Ensuring cyber resilience within this segment is crucial for maintaining the system's integrity, availability, and security in the face of cyber threats.

Infrastructure. Infrastructure includes the physical components and environment necessary for the functioning of technology. These can include hardware, networking equipment, cables, servers, data centers, and other elements that ensure the stability, reliability, and operation of the system.

The technical segment is a technological system. It is the human-made part of the socio-technical system. The functionality of the technical segment is determined by its ability to perform necessary tasks and provide required services. This includes developing, implementing, and maintaining various software products and services. When a particular social networking service gains popularity among actors, it provokes growth. Due to the scalability and clustering of the technical segment, the socio-technical system can expand and attract more elements (Fig. 4). A resilient technical segment begins with a robust infrastructure that can withstand various types of cyber threats. This includes employing high-quality hardware, reliable network equipment, and secure data centers. Redundant systems and failover mechanisms should be in place to ensure continuity in case of hardware failures or attacks.

The system's flexibility is determined by its ability to adapt to changing requirements and conditions. This includes quickly modifying, updating, and integrating new components. This is important for the functioning of the socio-technical system, as the number of elements is rarely constant and is always dynamic as a result of synergy with the socio-segment. One of the main indicators for the technological system is productivity per unit of time.

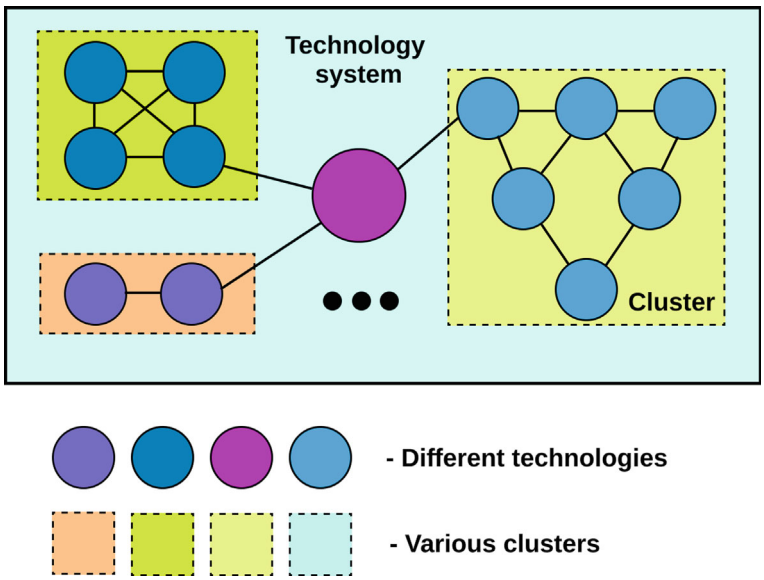

Fig. 4 Example of technology system

Cyber resilience within the technical segment of socio-technical systems necessitates a multifaceted approach encompassing robust infrastructure, secure architecture, preventive measures, continuous monitoring, effective incident response, data protection, and collaborative information sharing. By integrating these elements, organizations can establish a resilient technical foundation capable of withstanding, recovering, and adapting to cyber threats. This comprehensive strategy ensures that the technical segment not only supports but also enhances the overall cyber resilience of the socio-technical system.

2.3 Main Interactions

The interactions within socio-technical systems are fundamental to understanding their complexity and functionality. The dynamic interplay between actors and technological elements lies at the core of these systems. These interactions are not arbitrary but follow distinct clustering properties similar to those observed in technological systems, resulting in the modularization of elements into specific subsystems (Fig. 5).

Within socio-technical systems, the roles and responsibilities of actors are delineated based on their specific knowledge and skills, thereby shaping their interactions with the socio-technical system and its technological components. Cultural factors profoundly influence these interactions, which modulate how actors engage with technological tools and infrastructure. The clustering process within STS serves several pivotal functions: it facilitates the establishment of secondary goals within the socio-technical system and ensures synergy among elements within each cluster, thereby enhancing the productivity and effectiveness of these subgroups. Connections between clusters indicate a cohesive socio-technical system; the absence of such interconnections may suggest the existence of distinct, separate socio-technical systems. Numerous factors determine the number of actors, technologies, and clusters present in a socio-technical system, and it is not unrealistic to think these numbers can be programmed to correspond to the overall purposes of the system. Actors use technology to execute tasks, that is, to attain certain desired ends, and the interaction of these entities is often responsible for making users insist on modifications of technologies to serve them better. This is not unusual because the original intended use of a technological innovation changes over time, further underpinning the necessity for flexibility and adaptability in these systems.

Within the socio-technical system, connections are built between actors and technological elements. Following the clustering properties of technological systems, socio-technical system also tends to modularize elements into specific subsystems (Fig. 5). In each socio-technical system, actors have roles and responsibilities according to their knowledge and skills. Their interaction with the socio-technical system and technologies depends on the cultural aspect of the social segment. Clustering occurs to form secondary goals of the socio-technical system. This also ensures

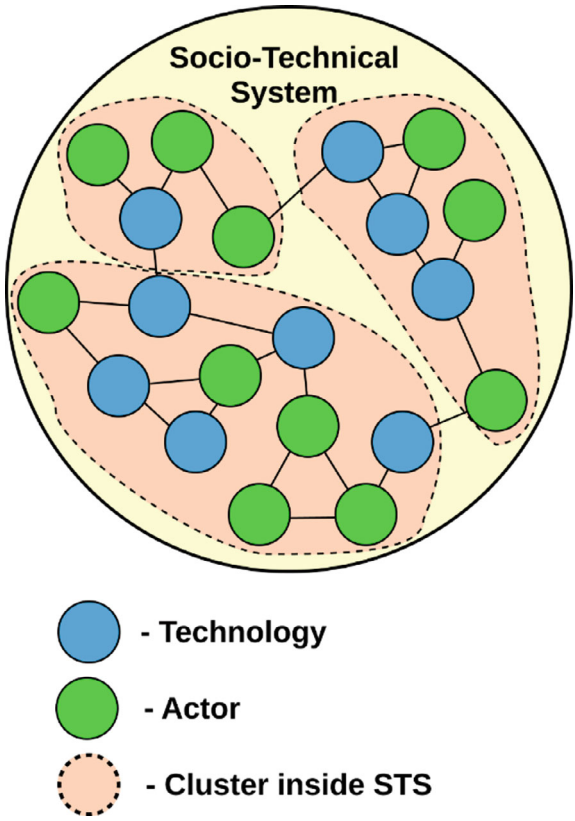

Fig. 5 Connections inside of socio-technical system

the synergy of elements within the cluster, increasing the productivity and effectiveness of this subgroup. There is always a connection between clusters within a single socio-technical system; if not, the system should be considered separate.

The number of actors, technologies, and clusters depends on various factors and can be regulated depending on the system's goal. Actors use technologies to accomplish tasks and achieve goals. Interaction between elements includes the adaptation of technologies to user needs. The original idea of technology creation may not always align with the needs for which it will eventually be used. Actors within one cluster have stronger connections with each other than with actors from other clusters, but these connections exist. Technologies within a cluster are integrated and enhance their functionality to solve the assigned task. Clusters exchange information with each other. Clustering is a crucial method for data analysis in virtual communities [2]. It helps classify large amounts of information and provides a qualitative assessment of users [2]. Actors can provide feedback on technology usage, while technological elements provide various analytics and reports that help actors make informed decisions. Within the socio-technical systems, there are two types of communication between clusters: intracluster and intercluster.

Intracluster communication refers to the exchange of information between nodes within the same cluster. This type of communication is typically characterized by low latency and high bandwidth [21]. In socio-technical systems, intracluster communication refers to interactions within a specific group or community. This can include communication between team members in an organization, departments within a company, or social groups within a community. Effective intracluster communication ensures that information flows smoothly and efficiently among members, fosters collaboration, and maintains coherence within the group. It often involves formal and informal communication channels, including meetings, emails, and social interactions, which help align goals, share knowledge, and build a supportive network.

Intercluster communication involves the exchange of information between nodes in different clusters. This type of communication usually has higher latency and lower bandwidth compared to intracluster communication due to the greater physical distances and potential differences in network infrastructure between clusters [21, 22]. Intercluster communication in socio-technical systems pertains to the exchange of information and interactions between different groups or communities. This type of communication is essential for broader collaboration, knowledge transfer, and innovation across the entire system.

Clustering within socio-technical systems is predicated upon a confluence of factors that collectively drive the formation of these groups. Central to this process are actors' functional roles and responsibilities, which facilitate effective collaboration among individuals performing analogous functions and tasks. Technological compatibility constitutes another critical determinant, wherein technologies inherently designed to function synergistically are grouped to optimize efficiency and functionality. This modularization streamlines the integration and maintenance of technological components. Furthermore, clustering is often aligned with common goals and objectives, ensuring a cohesive alignment of all cluster elements toward attaining shared outcomes.

Culture exerts significant influence, with clustering patterns often reflecting social interactions and cultural affinities among actors, thereby enhancing group cohesion. Geographical proximity is another salient factor, as clusters frequently emerge among actors and technologies situated in close physical proximity, reducing communication delays and logistical complexities. Lastly, the imperative of interoperability plays a pivotal role in clustering, ensuring that diverse components within the system can engage in effective communication and operational synergy. Collectively, these factors underscore the multifaceted nature of clustering within socio-technical systems, highlighting the intricate interplay between social, technical, and organizational dimensions.

Socio-technical system is a complex system capable of scaling to sizes that meet the requirements to achieve the set goal. The socio-segment and the technical segment are integrated. This process is fully managed by the actors of the system, and the technical segment responds to the requests and information received from the actors (Fig. 6). However, this is not a one-way relationship: actors are the driving force and decide how to use the system's technical segment, but they also receive signals that

prompt them to reassess their actions, change them, and make decisions based on the responses from the technical segment. An emergent property in the context of socio-technical systems is interoperability.

Interoperability is the ability of two or more software components to cooperate despite differences in language, interface, and execution platform [23]. In socio-technical systems, interoperability is the ability of different systems, components, and elements to interact effectively, exchange information, and utilize the system's resources to achieve goals. It arises when two or more systems synergize into a higher-level system. Interoperability encompasses all interactions between the socio and technical segments of the socio-technical system, as well as between different socio-technical systems as a whole. Four main aspects of interoperability in socio-technical systems can be identified:

- Technical interoperability—ensures stability and effective interaction between different technological elements of the socio-technical system.

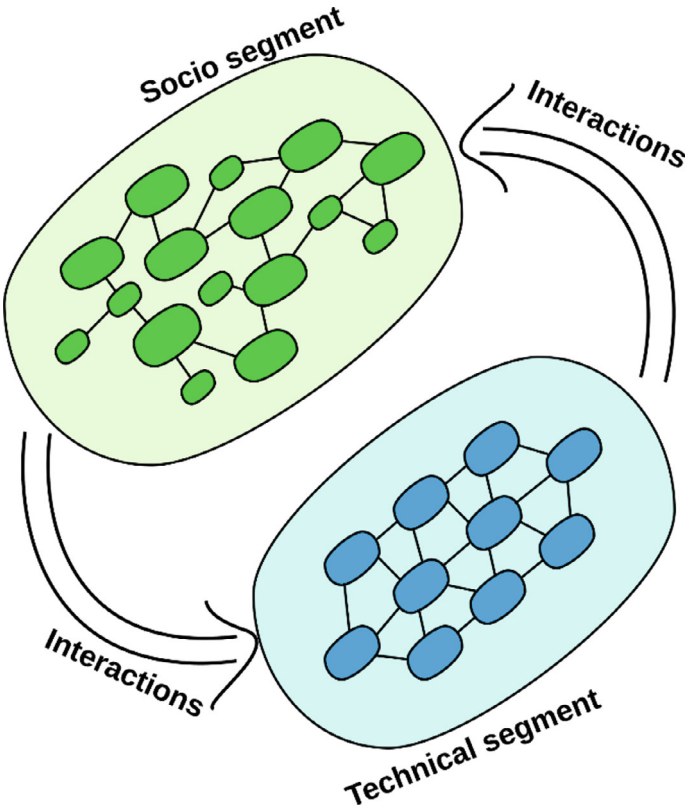

Fig. 6 Interactions between Socio and Technical segments

- Semantic interoperability is responsible for understanding information within socio-technical systems. It involves understanding information between actors and technologies and interpreting it between technologies and actors.
- Organizational interoperability involves structuring (clustering) actors and technologies within socio-technical systems. It includes aligning processes, policies, rules, norms, etc., to enhance efficiency and collaboration and achieve set goals.
- Social interoperability—exemplifies the interaction of actors with each other across different socio-technical systems.

Interoperability is a key feature of socio-technical systems, ensuring effective interaction between systems and subsystems (segments), components, and actors. It allows for improved coordination, information exchange, and resource sharing, which contributes to achieving set goals and enhances the system's overall efficiency. Thanks to interoperability, socio-technical systems can quickly adapt to changes and innovations, ensuring resilience and competitiveness in the modern world.

3 Social Networking Services as a Special Case of Socio-technical Systems

Social Networking Services are an example of Socio-technical systems as they combine technology and social interactions to create an integrated platform that supports communication, collaboration, and information exchange. Social networking services function as socio-technical systems [24] by considering their components, interactions, and impact on organizations, society, and actors. Detailed analysis by the team at Kepios [25] shows that there were 5.17 billion social media users around the world at the start of April 2024, equating to 63.7% of the total global population [26] (Fig. 7).

Almost everyone has an account on a particular social network or network. The use of social networks continues to grow, increasing by 5.8% over the past year [27].

Three groups of actors can be identified within social networking services:

- Users—they are active participants in social networking services. They can use social networking services platforms for communication, content (information) exchange, and interaction with other users. They create and consume content, maintain social connections, and participate in various virtual communities.
- Moderators and Administrators are actors equipped with tools that allow them to manage content (information) within social networking services, ensure compliance with rules and policies, and help users resolve issues.
- Developers—these actors are involved in developing the social networking services itself, its functionality, capabilities, connections, and tools for other actors.

An important aspect of the activity of actors is culture. Users of social networking services create their accounts for various reasons, and culture serves as a common

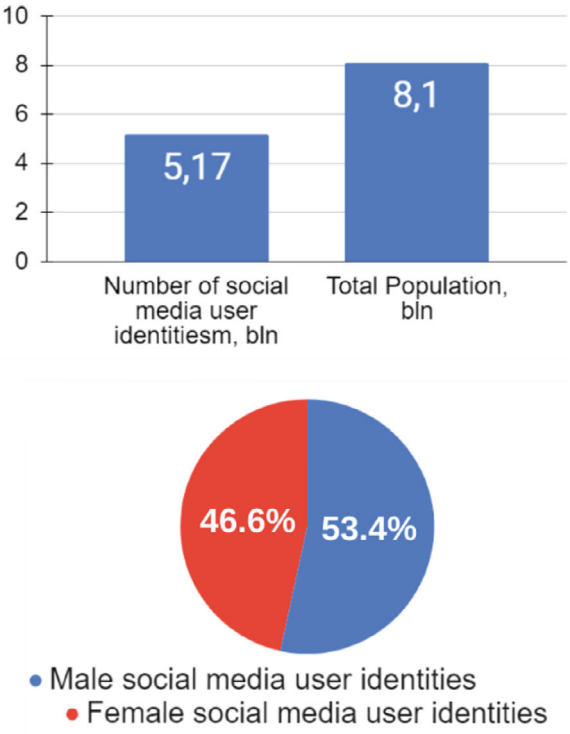

Fig. 7 Kepios [26] overview of social media use

answer. The culture of modern society is largely oriented towards digital interaction and online communication. Social norms and expectations push people to participate in digital communities where they can maintain connections with friends and family, meet new people, and exchange information and experiences. Additionally, self-expression and recognition in the eyes of others, achieved through publishing content and receiving likes and comments, are also significant cultural factors.

Cyber resilience refers to the capacity of socio-technical systems to anticipate, withstand, recover from, and adapt to adverse cyber events. Social networking services involve multiple layers of defense and recovery strategies to protect the technological infrastructure and the human actors engaged in these networks.

In the context of globalization and rapid technological development, having an account on social networking services becomes a standard for social participation and belonging to modern society. Facebook had 2.989 billion monthly active users in April 2023, placing it 1st in our ranking of the world's most 'active' social media platforms [17]. Millennials spend an average of 2 h and 38 min daily on social media, and 87% of millennials use Facebook regularly [28]. Although social networks are relatively new variations of socio-technical systems, they are rapidly developing and attracting users of all ages.

Their impact extends beyond social interaction, significantly influencing economic, political, and cultural landscapes on a global scale. Businesses utilize

social media for marketing, customer engagement, and brand building, establishing these platforms as essential components of modern commerce. Political movements harness social networks to mobilize supporters, disseminate information, and shape public opinion. Cultural trends and memes frequently originate and proliferate through these channels, thereby reflecting and shaping societal values and norms. Digital social channels like Facebook promote global interaction, but conflicts and harmful content require effective management to ensure information security. Technical tools, including user behavior analysis algorithms, are used to identify risks and make informed decisions. Thus, the socio-technical approach balances user social needs with technical capabilities, maintaining the healthy functioning of communities [5]. The pervasive nature of social media has also raised concerns regarding privacy, misinformation, and mental health. Despite these challenges, integrating social networks into daily life continues to expand, highlighting their role as powerful change agents in contemporary society. As these platforms evolve, they will likely play an increasingly significant role in shaping future social dynamics and interactions.

4 Vulnerabilities

Socio-technical systems have significantly more vulnerabilities due to their complexity. In the case of social networking services, any attack can lead to user data breaches, which can negatively impact the reputation of the company developing the platform. In 2020, Twitter admitted to at least 130 high-profile accounts being compromised. Over 50,000 Instagram accounts are hacked annually, with an attack occurring approximately every 10 min [29]. Meta was fined $265 million for failing to prevent a data breach that impacted 533 million users. This breach underscores the severe financial and reputational damage that can result from social media cyberattacks [29]. Cybercriminals often use phishing, infected ads, and social engineering techniques to compromise accounts. Infected ads account for 30–40% of social media infections [30]. These can generally be divided into three types of vulnerabilities for different aspects of socio-technical systems. One of the main aspects is technical vulnerabilities (Table 2).

In Table 1, only the basic vulnerabilities of socio-technical systems are presented. In reality, their list is constantly evolving, and over time, due to the development of artificial intelligence capabilities, cybersecurity, and cyberattacks will be carried out without direct user involvement. AI enhances cyberattacks by automating and scaling operations, making them faster and more efficient. It enables sophisticated phishing through personalized messages, creates advanced malware that evades detection, and develops deepfakes for disinformation [31].

The second main component of socio-technical systems is the socio-segment. Unlike technical vulnerabilities, system actors' vulnerabilities can be absolutely diverse and unpredictable. Table 3 presents the main social vulnerabilities.

Table 2 Technical vulnerabilities

Threat	Vulnerability	Consequences
Malware	Software vulnerabilities	Data theft, system disruption
DDoS	Inadequate network infrastructure protection	Denial of service
XSS	Insufficient input data filtering	Injection of malicious code
CSRF	Insufficient request authentication	Execution of unwanted actions on behalf of the user
Incorrect server configuration	Open ports, default settings	Unauthorized access to the system
Weak encryption keys	Use of short or predictable keys	Data theft or decryption
SSL/TLS certificate breaches	Unreliable certification authorities	Data theft in transit
Database attacks	Vulnerabilities in database query processing	Data theft, data modification, data deletion

Table 3 Socio vulnerabilities

Threat	Vulnerability	Consequences
Phishing	Insufficient user awareness	Theft of credentials, financial losses
Spear-phishing	Targeted attacks on specific individuals	Theft of confidential information
SMiShing	Phishing through text messages	Theft of personal data
Vishing	Phishing through phone calls	Theft of personal data
Social engineering	User gullibility	Theft of confidential information
Physical attacks	Manipulating people for access to information	Unauthorized access to objects
Fake accounts	Insufficient user verification mechanisms	Spread of misinformation, reputational damage
Bots	Automated accounts for spam or disinformation	Reduced interaction quality, misinformation
Trolling and cyberbullying	Anonymity and lack of control	Psychological pressure on users, demotivation
Content manipulation	Spread of fake news and disinformation	Misleading users, panic
Exploitation of personal data	Use of personal data without consent	Privacy violation, financial losses
Manipulation of public opinion	Use of paid bots and trolls	Influence on public opinion, political consequences

Social engineering poses the greatest threat to socio-technical systems today and in the future. The human factor in any system is the most unpredictable and can harm users and the system. In 2022, nearly 1.3 million unique phishing sites were detected worldwide, significantly increasing this type of attack [32]. Table 4 presents the most common types of vulnerabilities for socio-networking services in social engineering.

The vulnerabilities described in Tables 1, 2 and 3 are characteristic of socio-technical systems' technical and socio segments. It is appropriate to consider vulnerabilities inherent to the system as a whole. These can be characterized as System Vulnerabilities (Table 5).

While specialists constantly work on cyberattacks and threats to enhance security, the same cannot be said for the actors. Every user is vulnerable to any social networking services or socio-technical systems. The growing complexity of sociotechnical systems, which include interactions between humans, technology, and organizational structures, presents unique challenges for human factors and ergonomics professionals [33]. The main influence on actors is the culture within the social segment. By working with culture, the overall system security can be enhanced.

Table 4 Social engineering vulnerabilities

Threat	Vulnerability	Consequences
Pretexting	Use of fake scenarios	Theft of confidential information
Tailgating	Insufficient access control to premises, establishments, companies, etc.	Unauthorized physical access to the object
Eavesdropping	Lack of proper security measures in public places	Theft of confidential information
Baiting	Use of malicious USB drives	Data theft, system damage
Trust manipulation	Use of authority or friendly relationships	Theft of confidential information
Fake websites	Cloning well-known websites	Theft of credentials
Exploitation of fear	Use of fear or urgency to manipulate	Theft of confidential information
Impersonation	Use of a fake identity	Unauthorized access, information theft, reputational risks
Information gathering	Collecting information from open sources (OSINT)	Preparation of targeted attacks
Fake signatures	Use of forged signatures in emails	Theft of confidential information
Pseudo-support	Use of fake support services	Data theft or financial loss
Social experiments	Use of social experiments to obtain data	Privacy violation, user manipulation
Account cloning	Creating accounts with identical names and photos	Trust manipulation, data theft

Table 5 System vulnerabilities

Threat	Vulnerability	Consequences
Data leak	Insufficient protection of stored data. Data leakage through users	Unauthorized access to data, theft of confidential information
Lack or insufficient activity monitoring	Inability to promptly detect suspicious activity or security incidents	Delays in threat detection and response
Insufficient security audits	Irregular or superficial security checks of systems and processes	Missing potential vulnerabilities, creating opportunities for attackers
Insufficient incident awareness	Lack of proper threat notification and mitigation methods	Late response to threats, increased damage from incidents
Excessive privilege allocation	Users receiving more access than necessary	Data theft or privilege abuse
Insufficient data protection in transit	Lack of encryption or use of unsecured channels	Data theft during transit
Insufficient data protection at rest	Storing data in an unprotected state	Unauthorized access to data
Insufficient staff training	Lack of knowledge about cyber threats and protection methods	High vulnerability to social engineering attacks, improper incident handling
Lack of security policies	Undefined security rules and procedures	Unauthorized access, data loss, unprotected systems
Insufficient security funding	Lack of resources for implementing security measures	Ignored vulnerabilities, lack of necessary protection tools

5 Phygitality

Phygitality is a concept that combines physical and digital elements, creating integrated socio-technical systems. In other words, it is a process that blurs the boundaries between the digital and real worlds, between social and technical segments within socio-technical systems. Phygitality emerged in response to the need to merge physical and digital experiences, which was made possible by developing IoT, AR, and VR technologies. It allows users to interact with real objects through digital interfaces, enhancing user experience and system efficiency. Efficiency directly depends on the degree of actors' engagement (loyalty) in using technologies. The culture of the actors plays a role in this, as users may believe that incorporating technology into their personal lives poses potential risks, such as the leakage of personal information. To avoid this, actors need to be aware of the technological tools provided to them by socio-technical system developers.

Today, manifestations of phygitality in socio-technical systems are present in almost everything. For example, the concepts of smart cities and smart homes are

developed to use technology to automate many processes and improve users' lives. Using various sensors to monitor different aspects of a city, such as traffic, air quality, lighting, and water supply, allows for real-time monitoring and analytics, enabling quicker decision-making when necessary. Automating home systems, such as smart lighting, climate control, video surveillance, and electronic locks, are the initial examples of phygitality in our lives.

Smart cities and homes are complex systems that use advanced technologies to enhance quality of life, resource efficiency, and security. They represent the future of urban and home environments, where digital technologies are integral to everyday life.

Social networking services are actively developing AR and VR directions, allowing users to share their interactive experiences with each other. Interactive live streams are gaining popularity on platforms such as TikTok, YouTube, Facebook, Instagram, Twitch, and others. Viewers of the streams can directly influence the course of the broadcast, which significantly increases engagement in the process.

Geolocation services have significantly developed interactive possibilities for users, especially for participating in events, festivals, and local happenings. These services inform users nearby and invite them to participate. This is achieved through personalized recommendations, and using Big Data simplifies the entire process. By analyzing user interactions in the digital world, geolocation services can send personalized recommendations about content, events, products, and information potentially interesting to the user.

Socio-technical systems have created omnichannel interaction paths, which are actively used in marketing. Research on factors influencing consumer choices, such as consumer skepticism, psychological factors, price sensitivity, and others, and the ways potential buyers decide whether to purchase a product, result from omnichannel interaction between companies and customers [34]. In the context of social networking services and socio-technical systems, omnichannel interaction occurs by increasing actor engagement by implementing and using interactive elements and personalization. Phygitality allows actors to interact with content and events in new ways that were impossible before using socio-technical system technologies. The integrated experience of actors fosters stronger connections between the social and technical segments and between users and platforms.

6 Cyber Resilience

Cyber resilience is the ability of these systems to resist, recover from, and respond to adverse cyber events [35–38]. The proliferation of social networking services in society makes it important to have strong cyber resilience frameworks within these systems.

Socio-technical systems with social networking services are highly susceptible to cyber threats because there is a lot of interaction between the human actors and the technological components. Consequently, these interactions usually create more

than one entry point, thus susceptibility to cyberattacks, making it important for comprehensive measures to curb any cyber insecurity instances. Besides, the frequent and ever-growing sophistication of cyber threats has prompted technology to call for an advanced means of protection against increasing data breaches, unauthorized access, and system disruption.

This makes it critical for proactive security measures to anticipate and mitigate potential threats to ensure cyber resilience. This encompasses regular vulnerability assessments, deployment of intense, robust encryption protocols, and setting stringent access controls. Equally important is continuous monitoring of system activity to detect and respond to security incidents promptly. Such a proactive approach not only saves one from the headache of cyberattacks but also assures fast recovery and minimum disturbance in case of an incident. Cyber resilience involves multiple factors, including industry, government, research institutions, and society [39].

It is necessary to distinguish between cyber resilience techniques and resilience states within a system, as these factors must be addressed concurrently [40]. Figure 8 shows the main components of cyber resilience in socio-technical systems and social networking services.

Among the key components are human factors, threat intelligence, preventive measures, detection and monitoring, incident response and recovery, and information sharing (Fig. 8). Human factors are considered one of the major weaknesses of socio-technical systems. The users should be well-trained and made aware of possible threats to reduce the chances of human errors leading to breaches of security to a great extent. Periodic training and awareness programs are essential for all stakeholders to be fully vigilant against cyber threats. Culture influences how actors relate to the system, individually or communally. It will determine an attitude toward technology and security practices and how cyber risk management is conducted.

Fig. 8 Cyber resilience components of socio-technical systems

A culture that propagates awareness and best practices in cybersecurity enhances a sense of community toward vigilance and positive defense, which makes a resilient culture that improves the resiliency of the overall system.

Implementing robust preventive measures to safeguard against these cyber threats is essential, which may include strong encryption protocols, access controls, regular vulnerability assessments, and software updates. Preventive measures denote proactive actions to avert a probable risk before it can cause significant damage. Additionally, there is a need for continuous system activity monitoring for the early detection of security incidents. Using advanced monitoring tools, changes in network traffic, system activities, and user behavior are tracked to identify anomalies and potential security breaches in real-time, ensuring that any suspicious activity can be detected and responded to promptly. Cyber resilience practice involves designing and implementing a comprehensive incident response plan. This plan encompasses practices for detecting, responding to, and recovering from cyber incidents, including detailed procedures, roles, responsibilities, and communication processes. Effective incident response and recovery processes ensure rapid action and minimal disruption during a cyber incident. This requires effective communication and coordination among all actors involved in managing and mitigating the impact of incidents. In the technological segment, it necessitates deploying automated response mechanisms and maintaining the integrity and availability of technical resources during and after an incident. An effective information-sharing capability is crucial for establishing a collective defense against cyber threats. This involves communicating and collaborating with various system components and external entities, including other organizations, industry associations, and regulatory bodies. Sharing information on threats and vulnerabilities contributes to developing more effective strategies to counter cyber threats.

The components illustrated in Fig. 8 delineate a systematic approach for achieving cyber resilience in socio-technical systems [24, 41] with social networking services. Addressing human factors through training and awareness programs is essential to mitigate human errors that could lead to security breaches. Additionally, threat intelligence is vital for anticipating potential threats and constructing adequate defenses. A solid foundation of preventive measures and continuous monitoring of system activities is crucial for detecting and preventing cyber incidents.

Incident response and recovery processes ensure swift and minimal disruption following a cyber incident. In the socio-segment, actors must collaborate effectively, leveraging their knowledge within synergistic communication channels to respond efficiently. In the technology segment, systems must be robust and flexible, capable of isolating compromised areas, restoring services, and preventing further damage.

Moreover, information sharing is pivotal in enhancing the collective defense mechanism by enabling the exchange of knowledge and strategies to counter cyber threats. These components can be integrated into a comprehensive framework that bolsters the ability to resist, recover from, and adapt to cyber threats, creating a resilient cyber environment capable of withstanding and evolving in response to emerging cyber threats.

7 Conclusions

Conclusions drawn from the study of socio-technical systems and their integration with social networking services indicate that the sustainable functioning of such systems hinges on the harmonious interaction between technical and social components. Addressing social aspects, including culture, education, and social connections, is crucial to ensuring the efficiency and resilience of the socio-technical system. Furthermore, incorporating robust cybersecurity measures is essential to protect these systems from potential threats and maintain their integrity and reliability. Phygital solutions combine physical and digital elements and are becoming increasingly relevant in the modern world. They allow users to interact with real objects through digital interfaces, enhancing user experience and fostering the development of new forms of collaboration and communication. At the same time, ensuring cybersecurity remains critical for protecting systems from various threats. Processes occurring within socio-technical systems, such as communication, information management, automation, project management, and personnel development, are crucial for enhancing efficiency and effectiveness. Optimizing these processes will improve their functioning and ensure resilience in a dynamic environment. In this study, the structure of socio-technical systems has been delineated into distinct levels: the socio-segment, the technical segment, and their interactions. This stratification allows for a detailed consideration of human and technological factors, facilitating a balanced system design and implementation approach. The socio-segment encompasses actors, culture, and social interactions, while the technical segment includes technology and infrastructure. The interactions between these segments, such as communication and information exchange, are critical for the system's overall functionality.

This structured approach offers several advantages. Firstly, it identifies and addresses specific needs and challenges within each segment, enhancing system efficiency and resilience. Secondly, it supports the development of phygital solutions that seamlessly integrate physical and digital elements, promoting innovation and improved user experiences. In the future, this structure can be leveraged to develop more adaptive and robust socio-technical systems capable of responding to evolving technological and social landscapes. By continuously refining these levels and their interactions, researchers and practitioners can ensure socio-technical systems' continued relevance and effectiveness in addressing complex societal and organizational challenges.

The study has emphasized cybersecurity's critical role in maintaining socio-technical systems' integrity and functionality. Comprehensive matrices were developed to categorize various vulnerabilities across different system components, including technical, social, and system-wide vulnerabilities. These matrices provide a detailed analysis of potential threats and their consequences, offering valuable insights for developing effective mitigation strategies. Integrating these cybersecurity measures into the overall design and management of socio-technical systems is

paramount to safeguarding against cyber threats and ensuring the resilience of these complex systems.

Future research in socio-technical systems should prioritize addressing integration challenges, optimizing data management, and enhancing cyber resilience. Continuous innovation and adaptation to evolving technological and social landscapes are essential to ensure the sustained success of socio-technical systems in the future. This comprehensive analysis underscores the critical role of socio-technical systems in the digital age, providing a solid foundation for further scholarly inquiry and practical implementation. Cyber resilience, in particular, warrants significant attention, as it encompasses the capacity of these systems to anticipate, withstand, recover from, and adapt to adverse cyber events. Developing robust cyber resilience frameworks will be pivotal in safeguarding the integrity and functionality of socio-technical systems amidst an increasingly complex threat landscape.

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Particle Filter Application to Radio-Based Range-Only UAV Self-localization

Volodymyr Iatsyshyn

Abstract This work is aimed at searching for a relatively accurate and computationally efficient algorithm for range-only self-localization. Key requirement to the data sources is cost effectiveness. The radio signal strength indicator (RSSI)-based distance estimation model was chosen, due to wide availability of hardware and cost effectiveness. Key requirements to the algorithm are robustness towards noise introduced by RSSI-based distance estimation errors and flexibility to introduce additional data sources. Particle filter algorithm was chosen, because it satisfies both requirements, although it has bigger computational costs comparing to Kalman filter. A simulation environment was created to conduct experiments with assumed transmitted signal strength of 1 W and square root signal decay law. A Particle filter-based actor was implemented. Actor starts by translating geo-spatial coordinates of beacons into relative planar Cartesian coordinates, generates particles around beacons. Particles are placed with uniform distribution within a torus with co-planar circular axis radius equal to distance estimation. In each experiment, simulation software walks actor through a pre-defined path, compares obtained position estimates with expected state and calculates MAE and RMSE. Obtained results were satisfactory, in some cases showing MAE = 2.5981 and RMSE = 2.8474 after short stabilization period of few iterations. This period exists due to suboptimal initial particles placement. A Kalman filter-based actor was implemented as a comparison. A reference Kalman filter-based implementation showed slightly worse overall results with MAE = 12.5199 and RMSE = 13.2238. This can be explained by a lack of input from IMU. Further research will be directed towards UAV swarm self-localization and collision avoidance.

Keywords Particle filter · Self-localization · Kalman filter · RSSI-based localization

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1 Introduction

Unmanned Aerial Vehicle (UAV) is an aircraft that operates without a human pilot on board. UAVs can be controlled autonomously by onboard computers, remotely by a pilot via the ground station, or through a combination of both methods. UAVs vary greatly in size and capabilities, ranging from small, handheld devices to large, sophisticated aircraft. UAV applications are confined to the outdoors and indoor environments; commercial organizations and military forces, including surveillance, reconnaissance, target acquisition, and combat operations. UAVs offer several advantages over manned aircraft, such as reduced risk to human life, lower operating costs, and the ability to operate in hazardous environments.

When we discuss position monitoring, a common concern is whether Global Navigation Satellite System (GNSS) works reliably indoors or for military applications. Although GNSS has become a widely used technology for outdoor positioning, it struggles to provide reliable and accurate tracking within indoor environments. The primary reasons for this are twofold: weak signal strength and inherent limitations in technology's precision. Because of these limitations, alternative technologies have been developed to provide precise tracking and monitoring inside buildings. These alternatives, such as Wi-Fi positioning, Bluetooth/UWB beacons, and dedicated indoor positioning systems, use existing infrastructure or wireless signals within buildings to pinpoint the location of a device. We should point out the key limitation of these solution: its effective work range.

LoRa is a flexible technology that can be used for both indoor and outdoor positioning, offering excellent accuracy over a long communication range. In urban areas, LoRa can achieve accuracy within a range of up to 5 km, enabling reliable tracking and positioning. Its range extends significantly further in rural areas, reaching up to 15 km. This long-range capability makes LoRa an ideal solution for various applications, ensuring reliable and accurate location information in diverse environments. In our research, we leveraged LoRa technology along with machine learning techniques to predict UAV positions within indoor settings.

Reliable self-localization indoors [1] or in the absence of signals from GNSS is especially relevant in robotics and for autonomous unmanned systems. LiDAR and the SLAM algorithm [2] are usually used to solve this problem, which have proven themselves well when used in ground platforms operating indoors or in areas with enough landmarks. While this is a very effective approach, it requires expensive hardware and is computation intensive.

In this research we will focus on solving the problem of self-localization [3] of autonomous unmanned aerial vehicles operating in the absence of GNSS signals and following a predetermined route using radio beacon signals to determine their own position in space. To do this, we will use the Particle filter algorithm and compare its effectiveness with the Kalman filter algorithm [4, 5].

In this study, we will additionally impose constraints regarding the low cost and weight of the hardware, limiting the use of heavy and expensive devices such as LiDAR. Instead, we will assess the effectiveness of an algorithmic solution that

can run on compact and lightweight single-board computers or powerful microcontrollers. Such constraints are necessary for mass deployment in a swarm of autonomous UAVs [6, 7].

2 Related Works

In the paper [8], a 3D laser radar system is presented for detecting UAVs indoors. The system works by taking point cloud data from the UAV's LiDAR, identifying key points (edges and planes), and then comparing the data from two points in time to estimate the UAV's speed [9]. A point cloud map is also generated in the process. This method is then tested on a public dataset. The paper [10] proposes a different approach, utilizing radar frequencies.

In [11], authors tackle the issue of mobile WLAN Access Points affecting positioning accuracy using a method called Manifold Alignment with Mobile Access Point Detection. Another approach to indoor positioning is explored in [12], which relies on magnetic field measurements as the primary source of location information. In [13], a visual-inertial odometry localization method [14] based on fiducial markers is presented. This technology enables multi-rotor UAVs to navigate indoors and addresses the challenges associated with image-based indoor localization.

The research in [15] aims to explore indoor UAV localization using Bluetooth Low Energy (BLE) beacons. They strategically place BLE beacons throughout the environment and utilize signal strength or proximity information to estimate the UAV's position using suitable algorithms. In [16], authors investigated the feasibility of using UWB signals for precise indoor UAV positioning and proposed a localization method based on time-of-flight measurements.

Research [17] delves into indoor UAV localization using a deep-learning approach [18]. The authors present a Convolutional Neural Network (CNN) architecture to extract features from sensor data, enabling precise localization of the UAV indoors. In paper [19], a method for indoor UAV localization is described, which leverages Wi-Fi fingerprinting and supervised learning techniques. By collecting Wi-Fi signal strength data and applying machine learning algorithms, they achieve accurate positioning of the UAV.

In [20] authors present a technique for indoor localization of small UAVs using a combination of Ultra-Wide Band, a low-cost inertial measurement unit (IMU), and vision sensors. They propose an Extended Kalman Filter as a potential method for improving localization accuracy. This approach allows for the integration of visual odometry to recognize markers near the landing zone, and the use of a low-grade IMU during simulation. By incorporating ranging measurements, sensor errors arising from the suboptimal performance of accelerometers and gyros can be mitigated.

In this research, we focus on LoRa technology due to its reliability, noise tolerance and low cost.

3 The Problem

The problem of object localization involves determining the object's position based on its distances to several anchor points. In the context of indoor environments, these are typically points with known locations, such as Wi-Fi access points or Bluetooth/UWB beacons [3].

Range-only localization focuses exclusively on cases where only distance data to other objects (anchor points or landmarks) is available and is useful in situations where it is impossible or difficult to obtain information about the direction of the anchor points. A typical approach to solving this problem for three anchor points (see Fig. 1) is to approximately solve a linear system of equations (1), which allows estimating the object's location with a certain error.

$$\begin{cases} (x_0 - \hat{x})^2 + (y_0 - \hat{y})^2 + (z_0 - \hat{z})^2 = d_0 \\ (x_1 - \hat{x})^2 + (y_1 - \hat{y})^2 + (z_1 - \hat{z})^2 = d_1 \\ (x_2 - \hat{x})^2 + (y_2 - \hat{y})^2 + (z_2 - \hat{z})^2 = d_2 \end{cases} \tag{1}$$

Distance estimation to another object can be done in several ways: laser measurement, echolocation, received signal strength indicator (RSSI) [3], received signal delay, etc.

The decay of the received signal level is a physical phenomenon where the strength of the radio signal decreases with the distance traveled. It's important to note that this decrease is not linear and depends on several factors such as the environment, weather, presence of obstacles, and the frequency of the radio signal. Despite this complexity,

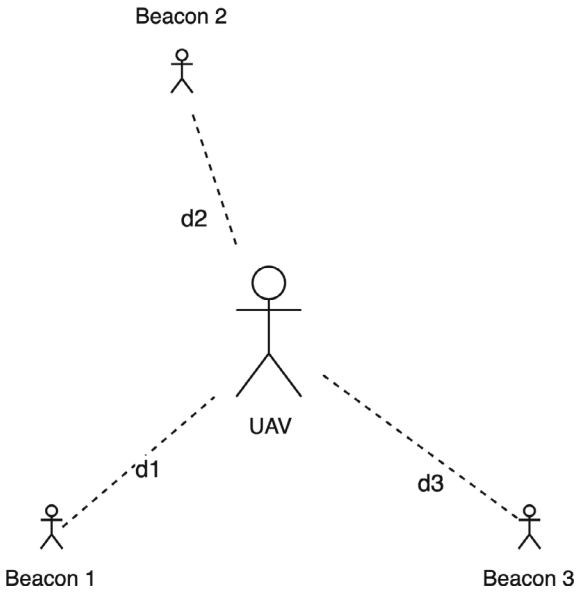

Fig. 1 Localization in indoor environments

RSSI can be modeled mathematically and the distance between the transmitter and receiver can be estimated. It's worth noting that in practice, one of the challenges of this method is the significant requirements for the quality of hardware and calibration of the model for specific conditions and operating environment.

The goal of the research is to find a relatively accurate and computationally lightweight algorithm for solving the self-localization problem, which can flexibly combine data from multiple sensors and demonstrate relative robustness to noise in the data.

4 Algorithm

The Particle Filters (PF) or sequential Monte Carlo methods are a set of Monte Carlo algorithms used to find approximate solutions for filtering problems [21]. This method is widely used in robotics for self-localization tasks [22]. The algorithm is based on a probabilistic approach to estimate the robot's position by generating and updating a set of hypothetical robot positions called "particles". The algorithm consists of the following steps:

1. Initialization: Initially, particles are generated in random possible positions of the robot. Each particle represents a hypothetical location of the robot and is defined as $P_i = \{x_i, y_i, w_i\}$.
2. Prediction: With each movement of the robot in space, the new position of the particle is estimated according to the robot's motion model. This prediction usually includes noise caused by sensor errors and inaccuracies.
3. Update: Data is collected from environmental sensors (e.g., LiDAR or camera) and compared to what these measurements would look like at each specific particle. Particles that agree well with the obtained data receive a higher weight, while others receive a lower weight.
4. Resampling: In this step, particles with high weight have a higher probability of "cloning," i.e., creating an additional particle near the original one. Particles with low weight may be discarded. Thus, there is a concentration of particles in more likely locations of the robot.
5. Iteration: Steps 2–4 are repeated with each movement of the robot and obtaining new measurements from environmental sensors. Thus, the distribution of particles changes over time and converges to the point where the robot is truly located.

The main advantages can be listed as follows:

- Flexibility: PF allows easy combination of data from different sensors.
- Robustness: PF is relatively resistant to noise present in sensor data, and can also work with multi-modal distributions, i.e., cases where the robot may have several probable locations.

- Handles non-linearity: PF provides good results even when the motion and/or sensor models are non-linear, unlike other filtering methods.

Among the drawbacks, it's worth highlighting the computational complexity compared to the Kalman filter, which puts somewhat higher demands on the robot's hardware.

Our PF-based implementation works iteratively. Every iteration consists of following steps:

- publish current state
- listen for other actors' (UAVs/beacons) state updates
- update current state and position estimates.

State attributes are listed in Table 1 and features actor's known geo-location, altitude, movement in 3 axes in last iteration and RSSI-based distance estimates to other actors in last iteration.

To estimate distance the following formula is used:

$$d_i = \sqrt{tss_i / rssi_i} + \varepsilon \tag{2}$$

where tss_i is the expected level of the transmitted radio signal, $rssi_i$ is the measured level of the received radio signal, ε is random noise with a Gaussian distribution.

Initially, actor estimates own position after receiving updates from at least 3 beacons (stationary geo-coordinates). These geo-coordinates are converted equidistant planar map projection and obtained values are used to approximately solve a linear system of Equation (1). Particle filter algorithm is used to estimate locations of other actors. Every actor is represented with own set of particles. Ground station (actor with ID 0) and beacons are represented with a small number of particles placed closely together. Particles for current actor are generated around estimated position with an offset by a random value with parameters $N(0, 5)$. Particles for other actors are generated around the current actor estimated position at corresponding distances, with an offset by a random value with parameters $N(0, 0.1d_i)$, where d_i is the estimated distance (see Fig. 2).

Table 1 Actor state attributes

	Attribute	Values	Description
1	ID	0…63	Actor ID, provided by ground station on take off
2	Latitude	− 90…90	(optional) if provided only by actors with verified geo-coordinates
3	Longitude	− 180…180	
4	Altitude	0…2048	FC altitude estimate
5	dx	− 512…511	FC or IMU movement estimates
6	dy	− 512…511	
7	dz	− 512…511	
8…72	distance	0…65535	Estimated distance to actors 0..63

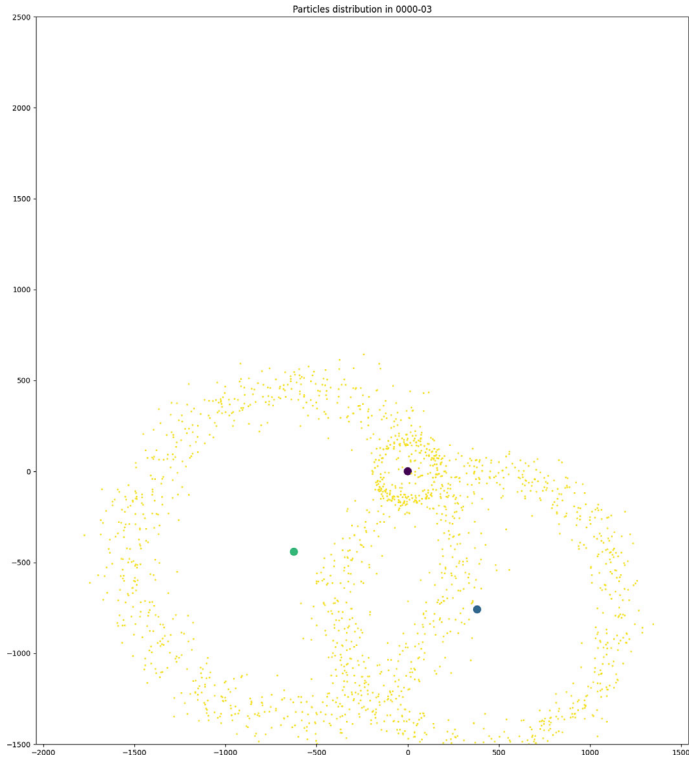

Fig. 2 Particle distribution at the 0th iteration

Every iteration UAVs' particles are moved according to received *dx*, *dy* and *dz*, then particles probabilities are updated to align with distance estimates made by actor and data received from others. After several iterations actors' particles converge to a true locations (see Fig. 3).

We must point out that proposed algorithm should show resilience to communication issues and recover from state update lost due to its probabilistic nature.

5 Simulation Environment

To assess the effectiveness of applying the Particle Filter (PF) to the range-only localization problem, a software simulation was developed in python. The software consists of several components (see Fig. 4): LoRa communication simulation layer, path planner, actor state manager, results assessment module and actors.

The software consumes agents written in python or C++ that implement specific interface (see Fig. 5). In total 3 agents were implemented including Particle filter-, Kalman filter- and liner approximation-based actors.

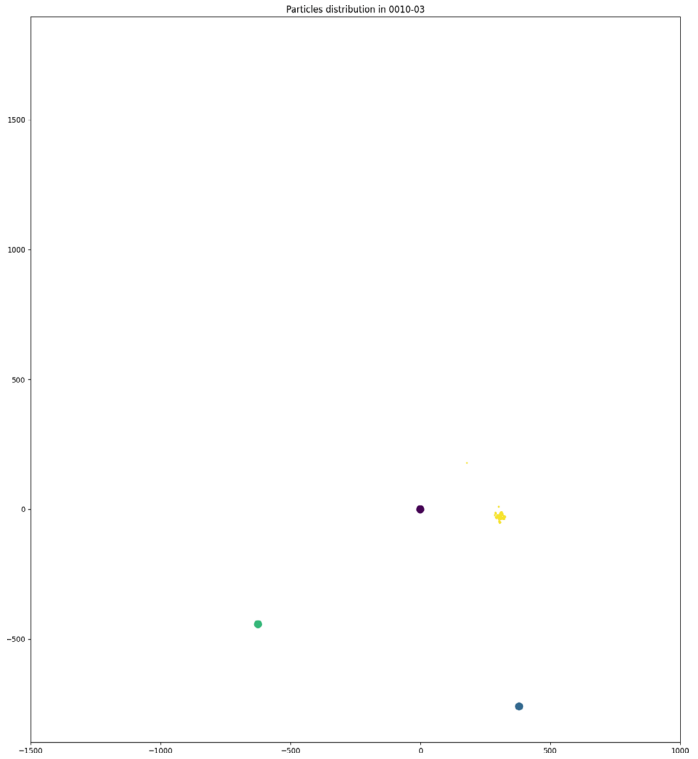

Fig. 3 Particle distribution at the 10th iteration

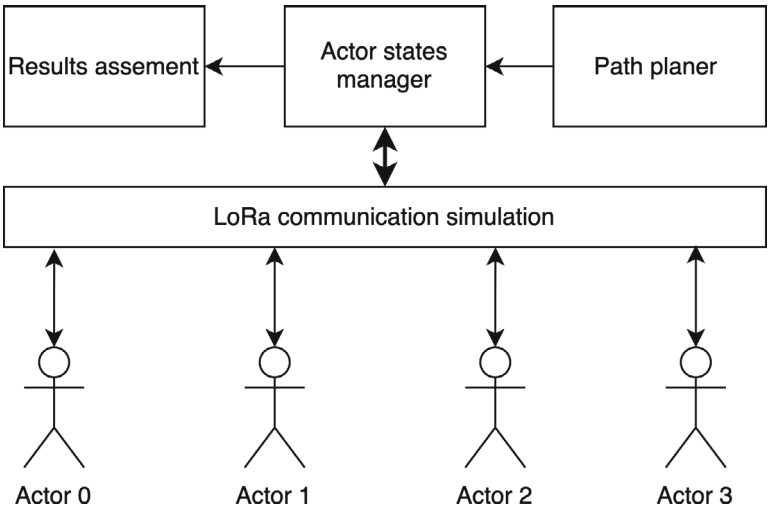

Fig. 4 Simulation software architecture

```
class BaseActor(object):
    def __init__(self, coordinates=None):

    def update_alt(self, alt):
        """ actor is provived with altitude estimate """

    def update_measurements(self, measurements):
        """ actor is prodived with RSSI measurements and previ-
ous states """

    def dump_state_self(self, dir, base_state, state, iteration,
actor_id):
        """ dump internal state to file """
```

Fig. 5 Base actor interface

LoRa communication simulation layer assumes constant transmission power $tss_i = 1$ W. Simulation step interval is assumed to be 1 s. On every transmission random noise with a Gaussian distribution is applied to transmission power and delay.

Path planner module is responsible for parsing and converting input file that defines starting location, checkpoints and movement speed for every actor. That input is used to calculate true location of actor at every iteration.

Actor state manager is responsible for collection of published actor states and distributing these between actors. It works in conjunction with results assessment module to compute accuracy metrics and capture intermediate actor states for further debugging purposes.

For every agent results assessment module calculates MAE and RMSE metrics using formulas (3) and (4). These metrics show how accurate estimates are.

$$MAE = \frac{\sum_1^N |x_i - \hat{x}_i|}{N} \tag{3}$$

$$RMAE = \frac{\sum_1^N (x_i - \hat{x}_i)^2}{N} \tag{4}$$

where x_i is true location, x_i hat is estimated location, N is number iterations.

Results for every actor are stored in csv file for further analysis actor (see Table 2). It includes true and estimated location, deviation and distance to ground station (GS).

Additionally, software creates a plot of true locations and estimates for every actor. This graph is used for manual verification (see Fig. 6). Also, particles distribution graphs are combined into a video with 1 frame per second rate. This gives additional option for visual inspection and debugging.

Table 2 PF-based actor results

Iteration	True X	True Y	Est. X	Est. Y	Deviation	Distance to GS
0	181.5	− 22.1	−130.4	− 557.6	619.7	182.9
1	196.4	− 24.3	−17.7	− 430.3	459.1	197.9
2	211.3	− 26.5	69.1	− 321.4	327.3	213.0
3	226.3	− 28.7	154.3	− 195.5	181.6	228.1
4	241.2	− 30.9	212.6	− 94.3	69.5	243.1
5	241.2	− 30.98	230.0	− 54.4	25.9	243.1
6	257.5	− 30.2	254.0	− 36.9	7.52	259.3
7	273.9	− 29.5	271.5	− 35.0	5.94	275.5
8	290.2	− 28.8	291.2	− 29.5	1.18	291.7
9	306.6	− 28.1	307.9	− 28.7	1.42	307.9
10	322.9	− 27.4	324.7	− 28.4	1.99	324.1
11	322.9	− 27.4	324.7	− 28.9	2.28	324.1
12	337.7	− 29.0	339.0	− 30.7	2.12	339.0
13	352.5	− 30.5	352.4	− 32.3	1.78	353.9
14	367.3	− 32.1	366.6	− 34.0	2.03	368.7
…						
138	1726.0	− 348.0	1723.9	− 349.1	2.35	1760.7
139	1741.8	− 349.9	1739.2	− 350.8	2.70	1776.6
140	1757.6	− 351.9	1755.9	− 353.0	1.99	1792.5
141	1773.4	− 353.9	1771.1	− 354.9	2.47	1808.3
142	1789.2	− 355.9	1786.6	− 357.2	2.85	1824.2

6 Testing Scenario

In this study we focus on the following base scenario that includes ground station, 2 stationary beacons and 1 UAV. Figure 7 shows positions of stationary beacons and yellow dots visualize path of UAV. This scenario will be used to test PF-based actor performance and accuracy. Results will be compared with Kalman filter-based and linear approximation-based actors.

To validate test scenario, linear approximation-based actor was created [23]. Its estimations are used as a base line when evaluating other implementations predictions. Figure 8 shows estimations as blue dots and actual position as red dot. Overall accuracy metrics for LA-based actor are MAE = 9.92 and RMSE = 10.69.

As observed initial estimations a very good, but accuracy is declining when UAV is traveling further away from beacons. This can be explained by limitation of multilateralization, as it is the most efficient when beacons are around the actor. In our case when distance to beacons becomes bigger than distance between beacons noisy readings have more impact.

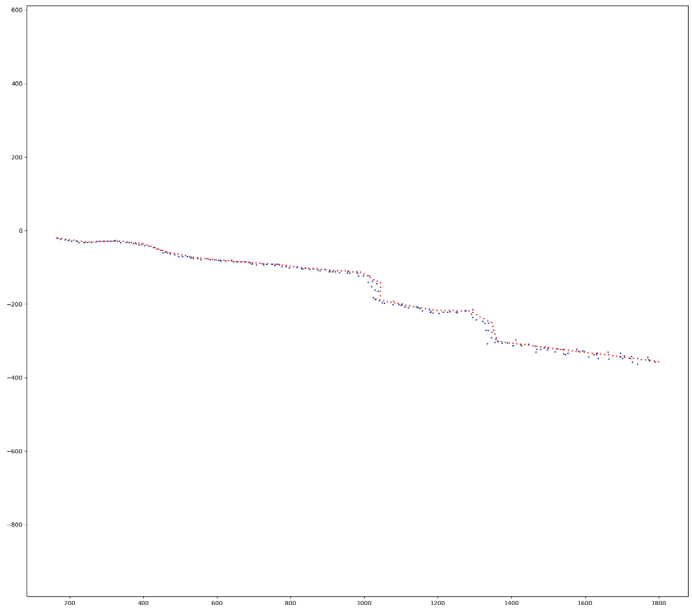

Fig. 6 Estimated (blue dots) locations versus true locations (red dots)

7 Results and Discussion

Table 2 presents the results of the simulation for Particle filter-based actor in the base scenario, specifically the intermediate results of the first 15 and last 5 simulation iterations. In this test, the PF agent achieves convergence within 8 iterations and subsequently maintains good accuracy in its estimates, namely MAE = 2.5981 and RMSE = 2.8474 (overall in the test MAE = 14.3011 and RMSE = 72.0219). Figure 9 shows true UAV locations as red dots and estimated locations are blue. We can observe that after 8 iteration absolute error is slightly increasing. This can be explained by the fact that UAV is moving away from beacons and thus noise in RSSI measurements starts to influence results. Nevertheless, such indicators are sufficient for operation in open spaces, however, require improvement for indoor operation.

For the comparison, simulations were carried out using the agent based on widely used Kalman Filter (KF). To implement this verification, the following approach was adopted: at each iteration, the system of linear equations (1) is solved, and the obtained results are fed into the KF for stabilization and noise filtration. This process is repeated a every iteration.

Table 3 presents the results of the simulation in the base scenario for KF-based actor. As observed, the KF-based agent exhibits good and stable results almost immediately and maintains MAE = 12.5199 and RMSE = 13.2238 throughout the simulation duration. These results might be improved by further tunning of KF parameters.

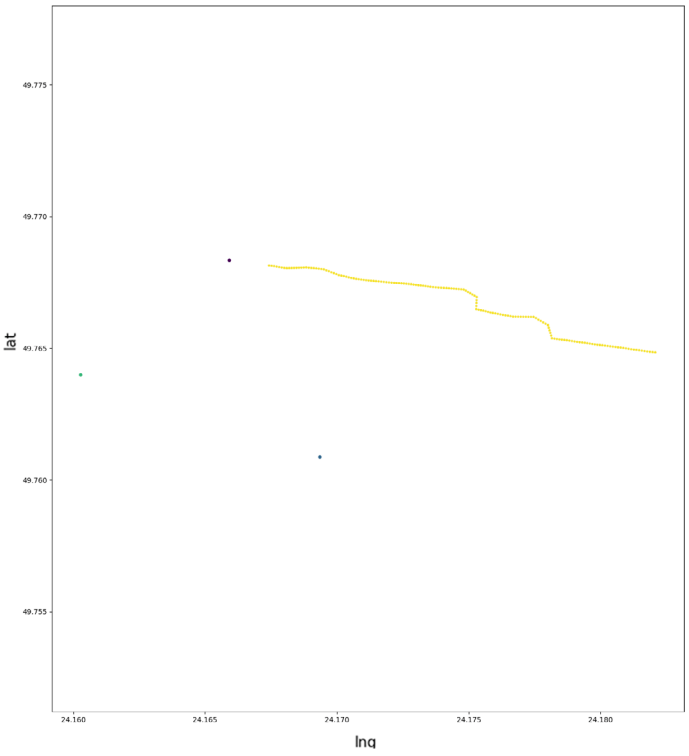

Fig. 7 Base scenario

Nevertheless, such indicators are not sufficient for operation in open spaces and should not be used without additional input data.

Figure 10 shows true actor locations as red dots and estimated locations are blue. As observed KF-based agent shows good results when UAV maintains course and has lower accuracy when actor is maneuvering.

Figure 11 presents an accuracy comparison of the PF-, KF- and linear approximation-based implementations in the base scenario. As observed, the PF-based agent shows superior accuracy after the initial stabilization period. This can be attributed to the fact that the input also includes data on the object's displacement from the inertial measurement unit. Also, we should point out that predictions made by PF-based actor are more accurate overall and in case of maneuvering, this is especially important for UAVs.

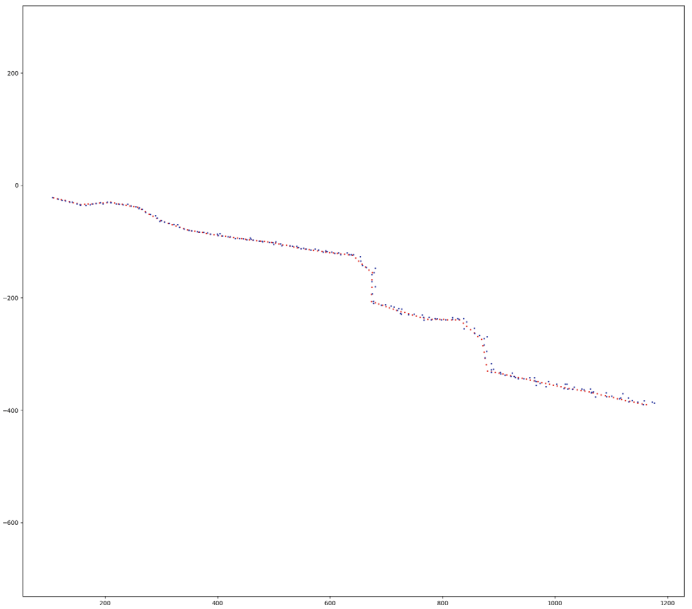

Fig. 8 LA-based actor estimated (blue dots) locations versus true locations (red dots)

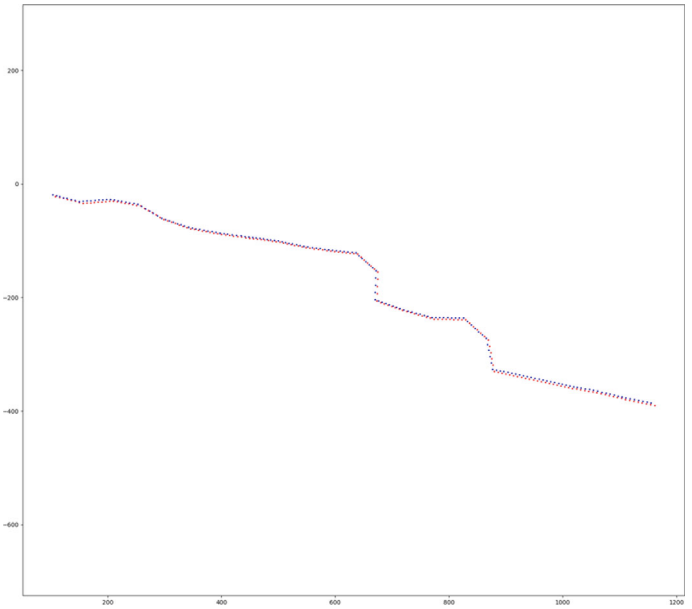

Fig. 9 PF-based actor estimated (blue dots) locations versus true locations (red dots)

Table 3 KF-based actor results

Iteration	True X	True Y	Est. X	Est. Y	Deviation	Distance to GS
0	0.2	− 1.8	99.6	− 38.2	18.4	110.8
1	0.2	− 1.8	139.1	− 6.7	34.4	110.8
2	7.1	− 3.6	131.5	− 36.3	20.7	117.9
3	14.0	− 5.3	127.6	− 39.6	15.4	125.0
4	21.0	− 7.0	135.5	− 39.5	14.1	132.1
5	27.9	− 8.8	145.4	− 40.5	15.1	139.2
6	34.8	− 10.5	155.6	− 38.3	15.0	146.3
7	41.7	− 12.2	161.4	− 39.0	13.6	153.4
8	48.6	− 13.9	163.1	− 36.7	7.0	160.6
9	48.6	− 13.9	169.0	− 32.8	12.4	160.6
10	55.2	− 13.5	176.5	− 33.0	13.3	166.9
11	61.9	− 13.0	181.6	− 29.3	12.3	173.3
12	68.5	− 12.5	196.0	− 29.2	19.8	179.8
13	75.2	− 12.0	201.5	− 30.4	18.4	186.2
14	81.8	− 11.5	202.0	− 31.9	12.2	192.7
…						
138	1024.4	– 363.8	1149.3	– 391.4	18.6	1195.7
139	1031.7	– 365.3	1162.5	–394.9	24.8	1203.1
140	1039.0	– 366.8	1172.0	– 382.6	25.3	1210.5
141	1046.3	– 368.4	1186.5	– 392.5	32.5	1217.9
142	1053.6	– 369.9	1175.0	– 394.8	14.2	1225.4

8 Future Work

Future research tasks include testing the algorithm performance in more advanced scenarios, including simulations of movement of multiple objects simultaneously and within a swarm, and testing the algorithm's robustness in the case of sporadic, temporary or permanent signal loss from some of anchor points.

Further research should be conducted to adapt the algorithm to collision avoidance and formation maintenance tasks in a swarm of UAVs. This is especially important because ensuring that the UAVs within the swarm do not collide with each other is crucial for the safety and integrity of the entire operation. With multiple UAVs operating in close proximity, the risk of collisions increases significantly. Effective collision avoidance algorithms and strategies are necessary to prevent accidents and damage to the UAVs. Also, maintaining a specific formation or pattern among the UAVs in a swarm is essential for achieving coordinated tasks. This could involve flying in a specific shape, maintaining relative distances, or adjusting positions based on the mission objectives. Formation maintenance requires precise control and communication among the UAVs to ensure they stay in the desired configuration.

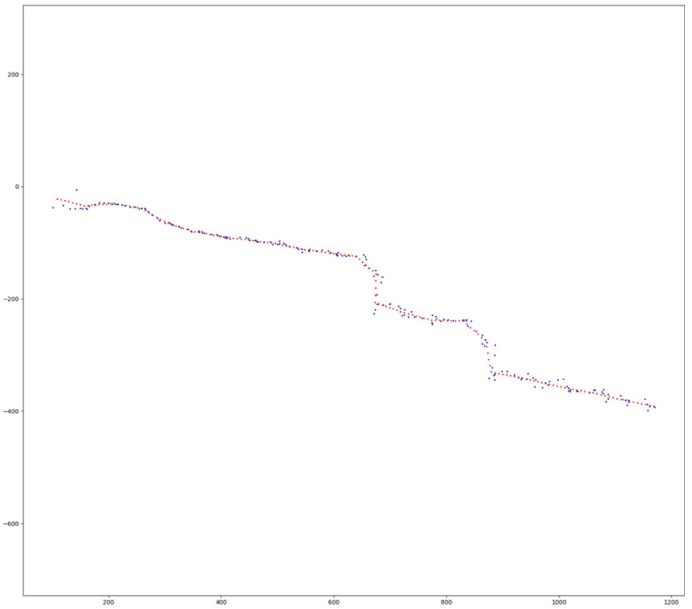

Fig. 10 KF-based actor estimated (blue dots) locations versus true locations (red dots)

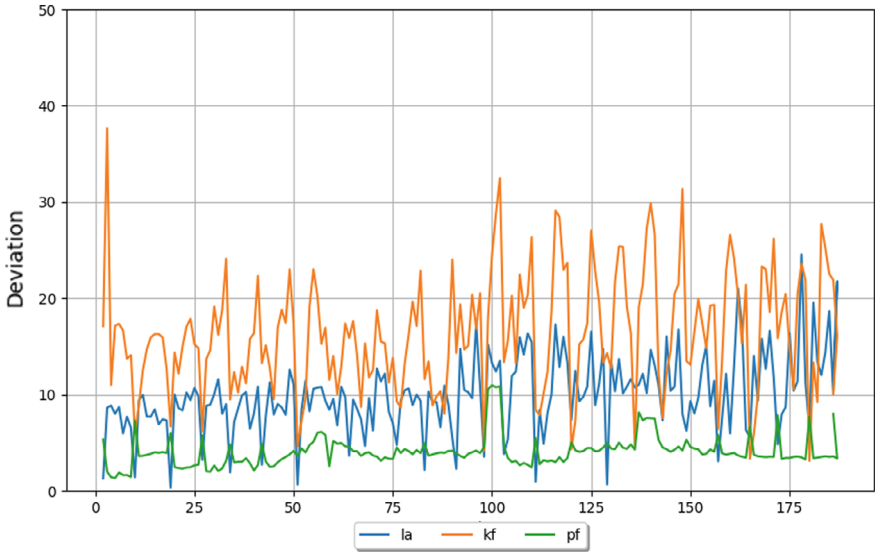

Fig. 11 Change in absolute estimation error over time

9 Conclusions

In this work, the problem of determining an object's position based on distance estimates to anchor points using RSSI was addressed. Given that RSSI-based distance estimation is quite inaccurate, the decision was made to apply filtering techniques. The agent based on Particle Filter algorithm exhibits relatively good noise robustness and, therefore, shows promising results in solving this problem. Among other advantages of the algorithm, its flexibility should be noted, which allows for easy integration of data from additional sensors.

During the research, a simulation environment was created, and a series of experiments were conducted. Sufficiently good accuracy and stability of position estimation were achieved, namely MAE = 2.5981 and RMSE = 2.8474 after the initial stabilization period in the base scenario. A comparison of the performance of the agents based on the Particle Filter and Kalman Filter algorithms was also carried out.

Future research tasks include extending the algorithm to work with multiple objects simultaneously and within a swarm, testing the algorithm's robustness in the case of signal loss from anchor points, and adapting it to collision avoidance tasks in a swarm of UAVs.

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The Impact of Selected Factors on Cost Stickiness in Central European Enterprises

Jan Musil

Abstract This article addresses the issue of cost stickiness in enterprises in the Czech Republic, Poland, and Slovakia. The aim is to compare the impact of geographical factors and company size on cost stickiness over 2018–2022, encompassing the pre- and post-COVID-19 pandemic periods. This research aims to contribute to a better understanding of business cost behavior during and after a crisis. The methodology is based on comparative analysis and employs a quantitative approach to calculate variables describing the cost stickiness of SMEs in the regions. Data collection is ensured through the Orbis Europe database for 2018–2022. Univariate statistical methods are used to achieve the research objectives. From the company size perspective, large and very large enterprises exhibited anti-stickiness behavior in the pre-pandemic period, whereas small enterprises demonstrated sticky behavior. During the COVID-19 pandemic, businesses, especially medium and very large enterprises, showed a high tendency toward cost stickiness. Post-pandemic, costs return to previous levels and grow more slowly than turnover. Geographically, businesses in the Czech Republic, Slovakia, and Poland exhibited slight cost stickiness before the pandemic. During and after the pandemic, the tendency towards stickiness changed, with Polish businesses showing the highest stickiness. This research provides a deeper understanding of cost stickiness in small and medium-sized enterprises in the Central European region, considering key factors (geographical, company size) during 2018–2022 before and after the COVID-19 pandemic. The research findings can be useful for managers in understanding cost behavior during periods of economic instability.

Keywords Cost-cutting · Cost management · SME · Sticky costs

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1 Introduction

Costs in the business environment are a key aspect of enterprise operations. The level of consumed costs significantly influences a company's performance and value creation. Companies face increasing competition, globalization, and rising customer expectations, which push them towards continuous cost reduction [26]. Cost reduction should be understood strategically, as long-term planned actions. However, in practice, companies often approach cost reduction reactively, only when they encounter difficulties [10]. To properly set up the cost-cutting process, it is essential to understand the current and individual cost development in each enterprise [1]. The asymmetric behavior of cost items is an important topic. The concept of asymmetric cost behavior, or cost stickiness, has been known for over 30 years. Ibrahim et al. [21] in their review summarize the gradual development in this area. Anderson et al. [1] developed a model for measuring cost response to changes in performance to evaluate cost asymmetry. They found that selling, general, and administrative (SG&A) costs in the USA increase by 0.55 percentage points (pp) with a 1 pp increase in demand, but decrease by only 0.35 pp with a 1 pp decrease in demand. This model has inspired further research with similar results, referred to as "cost stickiness" or "sticky costs." The article reviews the literature on sticky costs, then describes the data sample, and in the results section, it evaluates the impact of factors on cost stickiness using arithmetic methods and methods of mathematical statistics. The research sample comprises enterprises in the manufacturing industry from Central Europe—the Czech Republic (CZ), Poland (PL), and Slovakia (SK). The evaluated factors are: (i) company size factor ("CSF"), (ii) geographical factor ("GF").

2 Literature Review

Brasch [9] was one of the first to address the topic of asymmetric cost behavior and challenged the traditional cost behavior model with his findings that the cost curve for increasing levels of activity differs from the cost curve for decreasing levels of activity, leading to asymmetric cost behavior [24]. Noreen and Soderstrom [28] were pioneers who highlighted the asymmetric behavior of costs. They argue that the proportion of variable costs in overhead is small compared to fixed costs, and therefore, cost models based on proportionality should be used cautiously. Their research on hospitals showed that costs are not always proportional to activity. Cost stickiness, as named by Anderson et al. [1], is one of the main violations of symmetric cost behavior. This phenomenon describes how costs respond asymmetrically to increases and decreases in activity volume. Guenther et al. [18] in their study delve deeper into the reasons for asymmetric cost behavior and the emergence of cost stickiness, categorizing these reasons.

Legal reasons are primarily represented by personnel costs, where asymmetry arises from the adjustment of personnel costs during periods of declining demand—businesses in this situation must adhere to notice periods and other labor law attributes impacting corporate cost functions. Asymmetries in this area can also be seen in the potential for staff reductions by institutions, such as active trade unions. Their strength varies across countries, and their function, among other things, is to ensure greater social protection and job security, which also contributes to cost asymmetries. Other legal reasons include commitments from purchase contracts, which are also relatively inflexible, requiring consideration of notice periods—in the case of services, regular payments for services that are not regularly used (for instance, due to a decline in demand) [12, 18, 24]. Balakrishnan and Gruca [5] indicate that costs may not decrease proportionally with a decline in demand, as managers may decide to reduce resources and bear the associated adjustment costs. These costs include severance pay for employees during capacity reductions and costs for finding, hiring, and training new employees when demand recovers.

Reasons related to social and personnel policies are closely linked to employee care mentioned in the legal reasons. In the social and personnel domain, current enterprise goals may lead to reluctance to adjust resources during turnover declines. The style of personnel policy also influences asymmetric cost behavior, as personnel policies may include rules that avoid layoffs, showing externally that the company stands by its employees even during times of declining demand. Similar reasons might apply to disabled individuals or single mothers [24]. In some industries, social benefits are essential for recruiting qualified employees. Companies sometimes avoid layoffs to maintain a good reputation and employee morale, which could otherwise lead to increased turnover [1, 33]. Layoffs can result in higher organizational costs that need to be included in adjustment costs [1, 5].

Reasons related to corporate and operational policies also affect personnel, as companies often avoid laying off highly skilled workers and teams, leading to sticky costs. Demand recovery can be challenging due to the long adjustment period for new workers. Management anticipating a demand increase may hold unused assets due to high adjustment costs [1]. These costs may be higher than the costs of inactivity during periods of lower activity [18, 24].

Cost stickiness research includes industry-specific studies. Balakrishnan and Gruca [5] examined cost stickiness in hospitals and found that costs of key departments (e.g., direct patient services) are stickier than support department costs. Cannon [13] analyzed the US airline industry and identified determinants of cost stickiness. Bosch and Blandon [3] showed the impact of size and flexibility on cost stickiness using a sample of farms.

International evidence is abundant. Calleja et al. [12] report sticky cost behavior for American, British, French, and German firms. Banker and Byzalov [8] provided global empirical evidence that asymmetric cost behavior is a worldwide phenomenon. Medeiros and Costa [25] studied Brazilian firms, Bugeja et al. [11] Australian firms, and Cheng et al. [14] Chinese firms, finding that access to capital is a key factor in cost stickiness.

Determinants of cost stickiness in the context of strategy are examined by Ballas et al. [7], who analyze the influence of corporate strategy on cost asymmetry. Dalla Via and Perego [16] studied Italian firms (SMEs) and using the methodologies of Anderson et al. [1] and Weisse [32] demonstrate the stickiness of operating and wage costs and the anti-stickiness of SG&A and COGS. They state that only total labor costs exhibit cost stickiness, while SG&A, CoGS, and operating costs are not sticky.

Cohen et al. [15] find anti-sticky behavior in Greek local governments for administrative costs, while service costs are sticky. Dierynck et al. [17] found that company size affects cost stickiness—in small firms, layoffs are least expensive. Jeon [22] showed that narcissistic CEOs mitigate the negative impact of revenue declines on cost stickiness.

Balakrishnan et al. [6] found that fixed costs and logarithmic specification distort stickiness results. SG&A costs increase by 0.6608 pp with a 1 pp revenue increase and decrease by 0.1476 pp with a 1 pp revenue decrease. The COVID-19 pandemic can be considered a shock affecting firms [34], with negative news having a greater market impact [4]. Increased internal control and employee motivation can help control cost stickiness [31]. Cultural factors, such as Confucian culture, reduce cost stickiness [29].

While most research on this topic supports asymmetric cost behavior, Anderson and Lanen [2] provide a critical view on the theory that asymmetric cost behavior is the result of cost management.

Based on the literature review, the following hypotheses are summarized and will be tested:

H1: Company size has a statistically significant impact on cost stickiness coefficients.

The authors draw from Cheng et al. [14], who found that large companies exhibit sticky behavior in SG&A costs, while small and medium-sized enterprises exhibit anti-sticky behavior.

H2: The geographical factor has a statistically significant impact on cost stickiness coefficients.

The geographical factor is considered a determinant within the concept of 'cost culture' according to Himme [20].

3 Research Methodology

3.1 Data Sample

In the first phase, data collection was conducted from the Orbis Europe database. The following filters were used to establish the research sample: (i) geographical filter—selected countries were Poland, the Czech Republic, and Slovakia, and (ii)

available economic data for the years 2018–2022, specifically: Turnover and EBIT. The data sample is composed as follows for the years 2018–2022:

- Company ID
- Company Name
- Country of Operation
- Company Size
- Turnover (Revenue)
- EBIT.

3.2 Calculation of Indicators for Determining Cost Stickiness

For the study of cost stickiness, the cost-efficiency of individual companies is first quantified using the indicator "Total Operating Costs," which is calculated according to (Eq. 1), using the variables "Turnover" and "EBIT" from the data sample.

$$\mathrm{TOC_n} = \mathrm{TURNOVER_n} - \mathrm{EBIT_n} \tag{1}$$

where

$\mathrm{TURNOVER_n}$ is the Turnover for the *n*-th year,
TOCn is the Total Operating Costs for the *n*-th year,
$\mathrm{EBIT_n}$ is the EBIT for the *n*-th year.

In the research on cost stickiness, year-over-year changes in turnover and costs are tracked and further utilized through the variables Growth rate of TOC and Growth rate of Turnover.

(i) *Growth rate of the costs according to* (Eq. 2)

$$\mathrm{Growth_rate_of_TOC_{(n,n-1)}} = \frac{\mathrm{TOC_n} - \mathrm{TOC_{n-1}}}{\mathrm{TOC_{n-1}}} \tag{2}$$

where

$\mathrm{Growth_rate_of_TOC_{(n,n-1)}}$ is the growth rate of total operating costs in year *n* compared to year $n - 1$
$\mathrm{TOC_{n-1}}$ is the Total Operating Costs in year $n - 1$
$\mathrm{TOC_n}$ is the Total Operating Costs in year *n*.

(ii) *Growth rate of turnover according to* (Eq. 3)

$$\mathrm{Growth_rate_of_TURNOVER_{(n,n-1)}} = \frac{\mathrm{Turnover_n} - \mathrm{Turnover_{n-1}}}{\mathrm{Turnover_{n-1}}} \tag{3}$$

where

Growth_rate_of_Turnover$_{(n,n-1)}$ is the growth rate of turnover in year *n* compared to year $n - 1$.
Turnover$_{n-1}$ is the Turnover in year -1.
Turnover$_n$ is the Turnover in year *n*.

Subsequently, a dummy variable is introduced, which takes the value "0" when the "Growth_rate_of_Turnover(n,n − 1)" is positive, corresponding to a situation where the company's turnover increases year-over-year, and the value "1" when the turnover decreases year-over-year. This variable enables filtering for cases where the turnover decreases and where it increases year-over-year. This distinction is necessary to draw conclusions following the methodological procedure of, for example, Anderson et al. [1]. The quantification of cost stickiness for a given period in a specific company is ensured through the variable Sticky_coef *n* n, where "n" denotes the year, and the calculation is performed based on (Eq. 4):

$$Sticky_coef_n = \frac{Growth_rate_of_TOC_{n,n-1}}{Growth_rate_of_Turnover_{n,n-1}} \tag{4}$$

where

Sticky_coef_n je is the cost stickiness coefficient for year *n*.
Growth_rate_of_Turnover$_{(n,n-1)}$ is the growth rate of turnover in year *n* compared to year $n - 1$. Growth_rate_of_TOC$_{(n,n-1)}$ is the growth rate of total operating costs in year *n* compared to year $n - 1$.

The variable "Sticky_coef$_n$" is used in the research to draw conclusions about cost stickiness for a specific observation over a given period (annually). This variable expresses, in percentage points (pp), how much costs increase or decrease per 1 pp increase or decrease in turnover. The variable "Sticky_coef *n*" is influenced by factors whose impact and statistical significance are the subject of this research.

3.3 Calculation of Differences of Sticky_Coefficients

The median values of the cost stickiness coefficients are used to calculate the resulting values of cost stickiness because the median is often a better indicator of central tendency than the mean, as it is not affected by outliers. The mean is sensitive to extreme values, which can distort the results. The median provides a more robust measure of central tendency, especially for data with an asymmetric distribution [30].

Table 1 Company category

Company category	Small enterprises	Medium enterprises	Large enterprises	Very large enterprises
N	8597	7636	3765	827
%	41	37	18	4

Source Own data processing, based on Orbis Europe database, [2024]

3.4 Factors Influencing Cost Stickiness

In the previous methodological step, the data sample is extended by calculating variables that are used in the final step to quantify the cost stickiness of individual observations. The data sample includes variables representing factors whose influence on the resulting cost stickiness, expressed by the Sticky_coefficient, is examined.

3.4.1 Company Size Factor ("CSF")

The research data from the Orbis database were classified into small, medium, large, and very large enterprises. The representation of each group is shown in Table 1. For classification into four groups, the following coding was introduced ("1" = Small, "2" = Medium, "3" = Large, "4" = Very large).

Results indicate that the representation of small and medium-sized enterprises (SMEs) in the data sample is 78%, while large enterprises constitute only 22%. Further research focuses solely on SMEs due to their larger representation in the data sample.

3.4.2 Geographical Factor ("GF")

The research data of enterprises were classified in the matrix according to the geographical factor. For the variable "Country," numerical coding was introduced: "0" for Czechia (hereinafter "CZ"), "1" for Slovakia (hereinafter "SK"), and "2" for Poland (hereinafter "PL"), as shown in Table 2.

The data sample, from the perspective of the geographical factor according to Table 2, is composed of Polish enterprises, which represent approximately 40% of

Table 2 Country code

COUNTRY_CODE	CZ	SK	PL
N	3528	6136	6571
%	22	38	40

Source Own data processing, based on Orbis Europe database and IBM SPSS software, [2024]

the sample, followed by Slovak enterprises at 38%, and Czech enterprises at 22% of the sample.

3.5 Research on the Impact of Individual Factors on Cost Stickiness

In the research, univariate statistical methods were utilized, specifically the parametric statistical method ANOVA, followed by its non-parametric version (the Kruskal-Wallis test, hereafter referred to as the "K-W test") to assess the sensitivity of a specific factor. Statistically significant differences in the sample (between different groups of the factor variable) are subsequently compared using the parameter "Mean Rank" for the medians of values in scenarios where company revenues are increasing and decreasing. Based on these results, conclusions about cost stickiness or cost anti-stickiness are derived. These findings are further supported by comparisons, where in the case of the effect of the manufacturing industry factor, the term "effect" is used to indicate whether the test criterion in the K-W test assumes positive or negative values, thus allowing only for the inference of a positive or negative impact on the tested variable (in this case, cost stickiness).

The following statistical methods were used for the research:

ANOVA (Analysis of Variance) is a statistical method used to test the hypothesis that the means of more than two groups are equal. ANOVA examines the variance in the data and compares it between groups to determine if there are statistically significant differences between the means. This test requires that the data meet the assumptions of normality and equality of variances [27]. If the distribution is not normal and the dataset contains a large number of observations, parametric methods can be used [30].

Kruskal-Wallis H test is a non-parametric statistical test used to determine whether there are statistically significant differences between the medians of three or more independent groups. This test is suitable for analyzing data that do not meet the assumptions of normal distribution and equality of variances. The test statistic H is calculated based on the ranks of the values and compared to the critical value of the chi-square distribution [30].

4 Results

Results of Research on the Impact of Individual Factors on Cost Stickiness for the Geographical Factor and Company Size Factor.

Company Size Factor (CSF)

The factor of company size has been examined in early research on cost stickiness. For instance, Noreen and Soderstrom (Noreen and Soderstrom 1994) evaluated overhead costs in hospitals with respect to their size. The relationship between company size and cost stickiness has been demonstrated in a sample of companies [14], particularly in the context of large enterprises. The data set is divided into cases where companies' revenues increase year-over-year and cases where revenues decrease year-over-year, as cost stickiness is assessed using the same attributes.

In the initial phase of the research process, the data sample is tested using the parametric ANOVA method (Table 3).

The results of the ANOVA analysis (Table 3) indicate that the years prior to the COVID-19 pandemic are significant from the perspective of the "CSF," providing sufficient statistical evidence to reject the null hypothesis of equal variances between groups. In contrast, for the years 2020–2022, there is insufficient evidence to reject the null hypothesis (H0).

To complement this analysis, a non-parametric alternative to ANOVA—the Kruskal-Wallis test, which tests for distribution differences, and the Median test, which tests for median differences—was conducted (Table 4).

The results of the non-parametric ANOVA variant indicate significant outcomes in all observed years, as described in Table 4. The difference in significance can be

Table 3 ANOVA test results—CSF

ANOVA						
		Sum of squares	df	Mean square	F	Sig
STICKY_ COEF_2018	Between groups	15.574	3	5.191	20.582	**0.000**
	Within groups	5251.645	20,821	0.252		
	Total	5267.218	20,824			
STICKY_ COEF_2019	Between groups	108.885	3	36.295	8.666	**0.000**
	Within groups	87,200.589	20,821	4.188		
	Total	87,309.473	20,824			
STICKY_ COEF_2020	Between groups	23,537.736	3	7845.912	1.115	**0.342**
	Within groups	146,544,036.249	20,818	7039.295		
	Total	146,567,573.985	20,821			
STICKY_ COEF_2021	Between groups	22,247.670	3	7415.890	0.399	**0.754**
	Within groups	386,717,524.470	20,818	18,576.113		
	Total	386,739,772.140	20,821			
STICKY_ COEF_2022	Between groups	1078.198	3	359.399	0.856	**0.463**
	Within groups	8,740,791.716	20,821	419.807		
	Total	8,741,869.914	20,824			

Source Own data processing, based on Orbis Europe database, [2024]

Table 4 Kruskall-Wallis test results—CSF

Hypothesis test summary				
	Null hypothesis	Test	Sig.[a,b]	Decision
1	The medians of STICKY_COEF_2018 are the same across categories of COMPANY_ CATEGORY_ NUMERIC	Independent-samples median test	0.000	Reject the null hypothesis
2	The distribution of STICKY_COEF_2018 is the same across categories of COMPANY_ CATEGORY_ NUMERIC	Independent-samples Kruskal-Wallis test	0.000	Reject the null hypothesis
3	The medians of STICKY_COEF_2019 are the same across categories of COMPANY_ CATEGORY_ NUMERIC	Independent-samples median test	0.003	Reject the null hypothesis
4	The distribution of STICKY_COEF_2019 is the same across categories of COMPANY_ CATEGORY_ NUMERIC	Independent-samples Kruskal-Wallis test	0.005	Reject the null hypothesis
5	The medians of STICKY_COEF_2020 are the same across categories of COMPANY_ CATEGORY_ NUMERIC	Independent-samples median test	0.000	Reject the null hypothesis
6	The distribution of STICKY_COEF_2020 is the same across categories of COMPANY_ CATEGORY_ NUMERIC	Independent-samples Kruskal-Wallis Test	0.000	Reject the null hypothesis

(continued)

Table 4 (continued)

Hypothesis test summary				
	Null hypothesis	Test	Sig.[a,b]	Decision
7	The medians of STICKY_COEF_2021 are the same across categories of COMPANY_ CATEGORY_ NUMERIC	Independent-samples median test	0.000	Reject the null hypothesis
8	The distribution of STICKY_COEF_2021 is the same across categories of COMPANY_ CATEGORY_ NUMERIC	Independent-samples Kruskal-Wallis Test	0.000	Reject the null hypothesis
9	The medians of STICKY_COEF_2022 are the same across categories of COMPANY_ CATEGORY_ NUMERIC	Independent-samples median test	0.000	Reject the null hypothesis
10	The distribution of STICKY_COEF_2022 is the same across categories of COMPANY_ CATEGORY_ NUMERIC	Independent-samples Kruskal–Wallis test	0.000	Reject the null hypothesis

Source Own data processing, based on Orbis Europe database, [2024]
[a] The significance level is 0.050, [b] Asymptotic significance is displayed

attributed to the data characteristics and the robustness of the non-parametric test against outliers.

In the subsequent phase of the research process, considering the current results of the statistical analysis, non-parametric test variants are utilized—the Kruskal–Wallis H test and its descriptive statistics (Tables 5 and 6).

The descriptive data table of the sample (Tables 5 and 6) shows the number of companies along with their size characteristics (selected cases of the dataset for year-over-year revenue growth). This visualization also allows for the approximate ranking of different groups of companies based on their cost stickiness coefficient. When companies' revenues are increasing, they should aim to maintain lower cost stickiness coefficients, while in the case of declining revenues, they should aim to maintain higher cost stickiness coefficients from the perspective of lower economic performance of the company. The ranking of different groups of companies according

Table 5 Mean rank values—CSF—year 2018–2019

Year	2018				2019			
Turnover	Increase		Decrease		Increase		Decrease	
Category	N	Mean rank	N	Mean rank	N	Mean rank	N	Mean rank
Small	5284	7320.69	3313	3501.25	4537	6486.05	4060	4157.63
Medium	5164	6624.33	2472	3524.86	4813	6228.15	2823	4156.02
Large	2748	6604.71	1017	3488.39	2597	5956.27	1168	4206.29
Very large	592	6792.36	235	3840.09	554	5906.15	273	4114.57
Total	13,788		7037		12,501		8324	

Source Own data processing, based on Orbis Europe database, [2024]

to the "Mean rank" parameter (Table 6) clarifies the tendency toward cost stickiness in these groups of companies. The groups are ranked in the case of revenue growth (Inc) in ascending order (Asc) and in the case of revenue decline (Dec) in descending order (Desc).

The "Mean rank" values (Tables 5 and 6) are mathematically arranged in ascending or descending order in Table 7, meaning the value listed in Table 6 corresponds to the ranking of the company groups by size based on the cost stickiness coefficient. The rank "1" is designated as an excellent value, rank "2" as a good value, rank "3" as an average value, and rank "4" as a very poor value.

In the years before the outbreak of the COVID-19 pandemic, the tendency toward cost stickiness was higher for small and medium-sized enterprises. During the pandemic years and in 2022, the cost stickiness of small and medium-sized enterprises was the least—during revenue growth, the cost stickiness coefficients increased the slowest, and during revenue decline, they increased at a faster rate.

The Kruskal-Wallis H test output (Table 8) includes two key criteria: significance and the test statistic (Kruskal-Wallis H). The asymptotic significance, which is less than 0.001 in most of the observed time periods, indicates that the probability that the differences between groups are due to chance is less than 0.1%. This extremely low value suggests very strong statistical significance. The situation during the revenue decline (Dec) in 2018 and 2019 is evaluated as non-significant. In other situations, it can be concluded that at least one of the groups differs from the others in their medians. The test statistic is another parameter of the selected test, which can be used to determine whether there are statistically significant differences between the medians of more than two independent groups.

The greatest differences in the medians of the mentioned groups of companies are observed in 2020 during the revenue decline, followed by 2021 and 2022 during the revenue growth. Other values (where sig. < 0.05) are also high, but lower than those mentioned. In 2018 and 2019, during the revenue decline, very low values of the Kruskal-Wallis H test statistic were recorded, corresponding to very small (in 2019, rather negligible) differences in the medians of the cost stickiness coefficient among the defined groups.

Table 6 Mean rank values—CSF—year 2020–2022

Year	2020				2021				2022			
Turnover	Increase		Decrease		Increase		Decrease		Increase		Decrease	
Category	N	Mean rank	N	Mean rank	N	Mean rank	N	Mean rank	N	Mean rank	N	Mean rank
Small	3188	3520.28	5406	7217.89	5276	7046.45	3318	2888.43	4977	6694.67	3620	3241.76
Medium	2781	3845.33	4855	6327.46	5956	7680.86	1680	2699.19	5703	7411.86	1933	2937.5
Large	1269	3957.71	2496	6318.38	3236	8292.24	529	2615.11	3227	7911.33	538	2598.49
Very large	229	4117.69	598	6144.25	736	7921.82	91	3097.94	750	8402.76	77	2777.24
Total	7467		13,355		15,204		5618		14,657		6168	

Source Own data processing, based on Orbis Europe database, [2024]

Table 7 Ranking of "mean rank" values of cost stickiness coefficients—CSF

Year	2018		2019		2020		2021		2022	
Order	Asc	Desc	Asc	Desc	Asc	Desc	Asc	Desc	Asc	Desc
Turnover	Inc	Dec	Inc	Dec	Inc	Dec	Inc	Dec	Inc	Dec
Small	4	2	4	3	1	1	1	2	1	1
Medium	2	3	3	2	2	2	2	3	2	2
Large	1	1	2	4	3	3	4	4	3	4
Very large	3	4	1	1	4	4	3	1	4	3

Source Own data processing, based on Orbis Europe database, [2024]

A summary of the results on cost stickiness in relation to the "CSF" is illustrated in Table 9. The resulting difference, calculated using the differential method, represents the differences between the coefficients during revenue growth and revenue decline. The medians ("Med") of the cost stickiness coefficients "StickyCoef" for the years 2018 to 2022 for each company size ("S"; "M"; "L"; "VL") during revenue decline (DecTO) are subtracted from the medians ("Med") of the cost stickiness coefficients "StickyCoef" for the years 2018 to 2022 for each company size ("S"; "M"; "L"; "VL") during revenue growth (IncTO). The differential method is described by the following equations for each company size type (Eqs. 5–8):

Small (S)

$$\Delta\text{StickyCoef}_{2018-2022_S} = \text{Med}\left(StickyCoef_{2018-2022_{S,\text{Inc}_{TO}}}\right) - \text{Med}\left(StickyCoef_{2018-2022_{S,\text{Dec}_{TO}}}\right) \quad (5)$$

Medium (M)

$$\Delta\text{StickyCoef}_{2018-2022_M} = \text{Med}\left(StickyCoef_{2018-2022_{M,\ \text{Inc}_{TO}}}\right) - \text{Med}\left(StickyCoef_{2018-2022_{M,\ \text{Dec}_{TO}}}\right) \quad (6)$$

Large (L)

$$\Delta\text{StickyCoef}_{2018-2022_L} = \text{Med}\left(StickyCoef_{2018-2022_{L,\ \text{Inc}_{TO}}}\right) - \text{Med}\left(StickyCoef_{2018-2022_{L,\ \text{Dec}_{TO}}}\right) \quad (7)$$

Very Large (VL)

$$\Delta\text{StickyCoef}_{2018-2022_{VL}} = \text{Med}\left(StickyCoef_{2018-2022_{VL,\ \text{Inc}_{TO}}}\right) - \text{Med}(StickyCoef_{2018-2022_{VL,\ \text{Dec}_{TO}}} \quad (8)$$

Table 8 Test statistics—Kruskal-Wallis H test—CSF

Test statistics[a,b]										
Year	2018		2019		2020		2021		2022	
Turnover	Inc	Dec	Inc	Dec	Inc	Dec	Inc	Dec	Inc	Dec
Kruskal-Wallis H	99.325	6.375	41.818	0.534	59.675	179.323	170.387	26.106	223.465	83.775
df	3	3	3	3	3	3	3	3	3	3
Asymp. sig	0.000	0.095	0.000	0.911	0.000	0.000	0.000	0.000	0.000	0.000

Source Own data processing, based on Orbis Europe database, [2024]

[a] Kruskal Wallis Test

[b] Grouping variable: COMPANY_CATEGORY_NUMERIC

Table 9 Summary report of StickyCoeff – CSF

Report						
Year		2018	2019	2020	2021	2022
Sticky coefficients		Median	Median	Median	Median	Median
Inc of TO	Small	1.038	1.021	0.058	0.926	0.943
	Medium	1.003	1.009	0.184	0.961	0.985
	Large	0.997	0.998	0.186	0.985	0.998
	Very large	1.015	0.992	0.225	0.977	1.016
	Total	1.013	1.009	0.146	0.961	0.983
Dec of TO	Small	0.996	0.993	− 0.228	0.905	0.918
	Medium	0.995	0.993	− 0.415	0.839	0.822
	Large	0.998	0.985	− 0.393	0.790	0.690
	Very large	1.018	0.984	− 0.400	0.954	0.738
	Total	0.997	0.991	− 0.350	0.884	0.868
Difference	**Small**	**0.042**	**0.029**	**0.286**	**0.021**	**0.025**
	Medium	**0.008**	**0.016**	**0.599**	**0.123**	**0.163**
	Large	**− 0.001**	**0.014**	**0.579**	**0.195**	**0.309**
	Very large	**− 0.004**	**0.008**	**0.625**	**0.023**	**0.278**
	Total	**0.016**	**0.018**	**0.496**	**0.078**	**0.115**

Source Own data processing, based on Orbis Europe database, [2024]

In 2018, there was (albeit slightly) anti-stickiness behavior observed—specifically in large and very large enterprises. Costs decreased faster during revenue decline than they increased during revenue growth. The stickiest costs were observed in 2020 (the year of the COVID-19 pandemic), where costs continued to rise despite revenue declines. From the perspective of small and medium-sized enterprises, there was an improvement in the years following the pandemic, with cost stickiness returning to pre-pandemic levels.

Geographical Factor (GF)

The data sample includes companies from Central Europe—specifically from the Czech Republic (CZ), the Slovak Republic (SK), and the Polish Republic (PL). The relevance of this factor is confirmed by studies such as Kitching et al. [23], which analyzed cost stickiness data from companies in 39 countries, and Cheng et al. [14], which analyzed data from 38 countries, both confirming the geographical factor as relevant. In the initial phase of the research process, the data sample is tested using the parametric ANOVA method (Table 10).

The results of the parametric ANOVA indicate the necessity of employing non-parametric methods. Only the year 2018 shows significance with the parametric variant; for the other years, there is insufficient statistical evidence to reject the null hypothesis of equal variances among the groups. These findings suggest that this

Table 10 ANOVA test results—GF

ANOVA						
		Sum of squares	df	Mean square	F	Sig
STICKY_ COEF_2018	Between groups	6.704	2	3.352	12.775	0.000
	Within groups	4258.946	16,230	0.262		
	Total	4265.650	16,232			
STICKY_ COEF_2019	Between groups	24.911	2	12.455	2.820	0.060
	Within groups	71,694.040	16,230	4.417		
	Total	71,718.951	16,232			
STICKY_ COEF_2020	Between groups	19,715.886	2	9857.943	1.174	0.309
	Within groups	136,237,332.823	16,227	8395.719		
	Total	136,257,048.708	16,229			
STICKY_ COEF_2021	Between Groups	20,698.460	2	10,349.230	0.435	0.648
	Within Groups	386,450,000.743	16,227	23,815.246		
	Total	386,470,699.204	16,229			
STICKY_ COEF_2022	Between Groups	92.602	2	46.301	0.089	0.915
	Within Groups	8,431,809.496	16,230	519.520		
	Total	8,431,902.098	16,232			

Source Own data processing, based on Orbis Europe database, [2024]

analysis should be supplemented with a non-parametric variant of ANOVA—the Kruskal-Wallis test, which examines distribution differences, and the Median test, which evaluates differences in medians (Table 11).

The results of the non-parametric ANOVA variant indicate significant outcomes in all observed years, as described in Table 11. The differences in significance can be attributed to the data characteristics and the robustness of the non-parametric test against outliers.

In the subsequent phase of the research process, given the current results of the statistical analysis, non-parametric test variants are utilized—the Kruskal-Wallis H test and its descriptive statistics (Tables 12 and 13).

The descriptive statistics (Tables 12 and 13) provide information on the number of observations related to specific revenue situations (growth or decline) as well as the "Mean Rank" value, which allows for the approximate ranking of different groups of companies based on their cost stickiness coefficient. Based on this information in Table 14, the ranking of the average values can be determined—ascending (Asc) in the case of revenue growth and descending (Desc) in the case of revenue decline. The rank "1" is designated as an excellent value, the rank "2" as an average value, and the rank "3" as a poor value.

From this ranking, it is evident that before the COVID-19 pandemic, the best cost stickiness coefficient values were measured for companies based in the Polish

Table 11 Kruskall-Wallis test results—GF

Hypothesis test summary				
	Null hypothesis	Test	Sig.[a,b]	Decision
1	The medians of STICKY_COEF_2018 are the same across categories of COUNTRY_NAME	Independent-samples median test	0.000	Reject the null hypothesis
2	The distribution of STICKY_COEF_2018 is the same across categories of COUNTRY_NAME	Independent-samples Kruskal-Wallis test	0.000	Reject the null hypothesis
3	The medians of STICKY_COEF_2019 are the same across categories of COUNTRY_NAME	Independent-samples median test	0.000	Reject the null hypothesis
4	The distribution of STICKY_COEF_2019 is the same across categories of COUNTRY_NAME	Independent-samples Kruskal-Wallis test	0.000	Reject the null hypothesis
5	The medians of STICKY_COEF_2020 are the same across categories of COUNTRY_NAME	Independent-samples median test	0.000	Reject the null hypothesis
6	The distribution of STICKY_COEF_2020 is the same across categories of COUNTRY_NAME	Independent-samples Kruskal-Wallis test	0.000	Reject the null hypothesis
7	The medians of STICKY_COEF_2021 are the same across categories of COUNTRY_NAME	Independent-samples median test	0.000	Reject the null hypothesis
8	The distribution of STICKY_COEF_2021 is the same across categories of COUNTRY_NAME	Independent-samples Kruskal-Wallis test	0.000	Reject the null hypothesis

(continued)

Table 11 (continued)

Hypothesis test summary				
	Null hypothesis	Test	Sig.[a,b]	Decision
9	The medians of STICKY_COEF_2022 are the same across categories of COUNTRY_NAME	Independent-samples median test	0.000	Reject the null hypothesis
10	The distribution of STICKY_COEF_2022 is the same across categories of COUNTRY_NAME	Independent-samples Kruskal-Wallis test	0.020	Reject the null hypothesis

Source Own data processing, based on Orbis Europe database, [2024]
[a] The significance level is 0.050
[b] Asymptotic significance is displayed

Republic. With the onset of the COVID-19 pandemic, the ranking changes, and companies from the Czech Republic and the Slovak Republic move to the forefront.

The Kruskal-Wallis H test statistic (Table 15) demonstrates that significant results (Sig. < 0.05) occur in most of the observed periods. This indicates a statistically significant difference between the medians of at least one pair of groups. In other words, we can reject the null hypothesis, which states that all groups have the same median. This value suggests that the variability in the data between groups is not random and that at least one group differs significantly from the others.

The Kruskal-Wallis H test criterion, visualized in Table 15, indicates greater differences between the groups in the data sample, particularly during revenue growth in 2018 and revenue decline in 2020. In the case of revenue growth in 2022, the test criterion value is 3.963—a low value for this criterion—suggesting that the differences between groups are not significant.

The summary of results on cost stickiness concerning the company size factor is illustrated in Table 16. The resulting difference, calculated using the differential method, represents the differences between the coefficients during revenue growth and revenue decline. The medians ("Med") of the cost stickiness coefficients "StickyCoef" for the years 2018–2022 for each country where the company is based ("CZ"; "PL"; "SK") during revenue decline (Dec_{TO}) are subtracted from the medians ("Med") of the cost stickiness coefficients "StickyCoef" for the years 2018 to 2022 for each country where the company is based ("CZ"; "PL"; "SK") during revenue growth (Inc_{TO}). The differential method is described by the following equations for the groups of companies from each country (Eqs. 9–11):

Czech Republic:

$$\Delta \text{StickyCoef}_{2018-2022_{CZ}} = \text{Med}\left(StickyCoef_{2018-2022_{CZ,\ Inc_{TO}}}\right) - \text{Med}\left(StickyCoef_{2018-2022_{CZ,\ Dec_{TO}}}\right) \quad (9)$$

Table 12 Mean rank values—GF—year 2018–2020

Year	2018				2019				2020			
Turnover	Increase		Decrease		Increase		Decrease		Increase		Decrease	
Country	N	Mean rank	N	Mean rank	N	Mean rank	N	Mean rank	N	Mean rank	N	Mean rank
CZ	2196	5133.37	1332	2827.63	2022	4706.33	1506	3389.32	1201	3027.64	2327	4958.26
SK	4236	5575.98	1900	2832.15	3370	4845.23	2766	3490.74	2527	2931.37	3606	5397.2
PL	4016	4903.6	2553	2972.39	3958	4515.23	2611	3420.75	2241	3022.62	4328	5002.08
Total	10,448		5785		9350		6883		5969		10,261	

Source Own data processing, based on Orbis Europe database, [2024]

Table 13 Mean rank values—GF—year 2021–2022

Year	2021				2022			
Turnover	Increase		Decrease		Increase		Decrease	
Country	N	Mean Rank	N	Mean Rank	N	Mean Rank	N	Mean Rank
CZ	2588	5824.35	940	2538.37	2527	5281.09	1001	2930.64
SK	3870	5626.01	2263	2595.24	3948	5300.65	2188	2861.83
PL	4774	5496.12	1795	2358.44	4205	5413.62	2364	2633.43
Total	11,232		4998		10,680		5553	

Source Own data processing, based on Orbis Europe database, [2024]

Table 14 Ranking of "mean rank" values of cost stickiness coefficients—GF

Year	2018		2019		2020		2021		2022	
Order	Asc	Desc	Asc	Desc	Asc	Desc	Asc	Desc	Asc	Desc
Turnover	Inc	Dec	Inc	Dec	Inc	Dec	Inc	Dec	Inc	Dec
CZ	2	3	2	3	3	3	3	2	1	1
SK	3	2	3	1	1	1	2	1	2	2
PL	1	1	1	2	2	2	1	3	3	3

Source Own data processing, based on Orbis Europe database, [2024]

Table 15 Test statistics—Kruskal-Wallis H test—GF

Test statistics[a,b]										
Year	2018		2019		2020		2021		2022	
Turnover	Inc	Dec	Inc	Dec	Inc	Dec	Inc	Dec	Inc	Dec
Kruskal-Wallis H	104.983	10.331	27.542	3.022	4.251	45.230	17.247	27.801	3.963	34.281
df	2	2	2	2	2	2	2	2	2	2
Asymp. sig	0.000	0.006	0.000	0.221	0.119	0.000	0.000	0.000	0.138	0.000

Source Own data processing, based on Orbis Europe database, [2024]
[a] Kruskal Wallis Test
[b] Grouping Variable: COUNTRY_CODE

Poland:

$$\Delta \text{StickyCoef}_{2018-2022_{PL}} = \text{Med}\left(StickyCoef_{2018-2022_{PL,\ Inc_{TO}}}\right) - \text{Med}\left(StickyCoef_{2018-2022_{PL,\ Dec_{TO}}}\right) \quad (10)$$

Slovakia:

Table 16 Summary report of StickyCoeff—GF

Report						
Year		2018	2019	2020	2021	2022
Increase of turnover	CZ	1.011	1.017	0.141	0.967	0.964
	PL	0.999	1.003	0.143	0.922	0.969
	SK	1.040	1.025	0.097	0.965	0.978
	Total	1.017	1.015	0.129	0.948	0.971
Decrease of turnover	CZ	0.990	0.990	− 0.375	0.901	0.920
	PL	1.000	0.987	− 0.372	0.835	0.823
	SK	0.990	0.999	− 0.246	0.920	0.921
	Total	0.996	0.993	− 0.330	0.887	0.884
Difference	CZ	0.021	0.027	0.516	0.066	0.044
	PL	− 0.001	0.016	0.515	0.087	0.146
	SK	0.050	0.027	0.343	0.045	0.058
	Total	0.021	0.022	0.459	0.062	0.087

Source Own data processing, based on Orbis Europe database, [2024]

$$\Delta \text{StickyCoef}_{2018-2022_{SK}} = \text{Med}\left(StickyCoef_{2018-2022_{SK,\ Inc_{TO}}}\right) - \text{Med}\left(StickyCoef_{2018-2022_{SK,\ Dec_{TO}}}\right) \quad (11)$$

In the pre-pandemic period, the highest cost stickiness is exhibited by companies from the Slovak Republic and the Czech Republic (Table 16). For companies from Poland, the year 2018 shows a situation of anti-stickiness, although the value is minimal. During the COVID-19 pandemic, however, costs continue to rise despite declining revenues for all mentioned groups of companies, resulting in increased stickiness coefficients. In 2021, all groups of companies show very cautious cost increases during revenue growth and a significant improvement in resulting stickiness. For companies from the Czech Republic, the situation continues to improve in 2022. However, companies from Poland and Slovakia experience higher cost growth rates, with Polish companies also exhibiting slower cost decrease rates during revenue declines.

5 Discussions

The results of the research on cost stickiness from the perspective of two selected factors largely align with previous studies on similar topics. In the case of the company size factor (CSF), the findings can be compared with the study by Dalla Via and Perego [16], which evaluates wage costs as sticky only in small and medium-sized enterprises. Cheng et al. [14] also delve into cost stickiness from the perspective

of company size, finding that sticky costs are more characteristic of large companies, while small and medium-sized enterprises tend to exhibit anti-stickiness. On average, their study of a sample of Chinese firms demonstrated anti-stickiness. The chosen time period of 1999–2007 by Cheng et al. [14] also does not encompass (or only barely includes) the COVID-19 pandemic or the global financial crisis of 2007–2015, both significant events impacting the economy [34].

From the perspective of the company size factor (CSF), analyses have also extended to the nonprofit sector. Habib and Huang [19] evaluate cost stickiness in nearly 90,000 charitable organizations in New Zealand. Their research aligns with the findings of Cheng et al. [14] in the context of the company size factor, indicating that large charitable organizations are more prone to cost stickiness than small ones. They also find that the degree of cost stickiness is higher during crisis periods than in non-crisis periods.

The results of this article concerning the company size factor align with the research by Cheng et al. [14] on anti-stickiness behavior in large and very large enterprises in the pre-pandemic period. For small and medium-sized enterprises, slight cost stickiness was observed in the pre-pandemic period. In the post-pandemic period, there is a gradual improvement in stickiness coefficients across all company size groups, although only the small enterprises return to pre-pandemic stickiness levels within the observed years. This improvement is mainly due to the very conservative approach of small enterprises regarding cost increases during revenue growth—costs grow more slowly than revenue in the post-pandemic period across all company sizes, with the slowest growth observed in small enterprises.

Regarding the second selected factor, the geographical factor, Kitching et al. [23] evaluated cost stickiness in over 50,000 companies from 39 countries. Their results confirmed the hypothesis that national culture influences resource management decisions, leading to differences in cost stickiness across countries. However, in this case, the hypothesis by Kitching et al. [23] cannot be confirmed for the pre-pandemic period, as the differences in stickiness coefficients between the selected countries (CZ, SK, PL) are minimal. Cost stickiness coefficients from the perspective of the geographical factor change significantly only during the COVID-19 pandemic (particularly in 2020), during which companies exhibit substantially higher stickiness. Significant differences in cost stickiness coefficients by geographical factor are observed during this period—the lowest stickiness during the crisis is exhibited by Slovak companies, confirming the hypothesis by Kitching et al. [23] regarding the influence of the geographical factor on cost stickiness during a crisis (COVID-19 pandemic). Differences in cost stickiness occur even between countries with similar national cultures (CZ vs. SK, PL vs. SK). In the post-pandemic period, cost stickiness slowly returns to pre-pandemic levels, but the situation worsens due to the pandemic, as the stickiness in the last observed year is four times higher than in 2018. This conclusion is also supported by the research of Habib and Huang [19], who state that the degree of cost stickiness is higher during crisis periods than in non-crisis periods.

6 Conclusion

The article addresses cost stickiness in enterprises from Central European countries (Czechia, Slovakia, and Poland). Using arithmetic methods and statistical analysis, cost stickiness is first determined via the cost stickiness coefficient, StickyCoeff. This established stickiness is then compared from the perspectives of two selected factors: the company size factor (CSF) and the geographical factor (GF). The research employs univariate statistical methods—ANOVA and the Kruskal-Wallis test—and subsequently evaluates stickiness from the perspective of medians. The summary of the research results highlights the calculation of the differential value of the medians of the cost stickiness coefficients for cases of revenue growth and decline.

From the perspective of the company size factor (CSF), anti-stickiness behavior is observed in large and very large enterprises during the pre-pandemic period, while small enterprises exhibit sticky behavior. During the COVID-19 pandemic, companies display a high tendency towards cost stickiness, especially medium-sized and very large enterprises. In the post-pandemic years, a gradual return to previous values is observed, where cost increases are kept relatively conservative during revenue growth (costs grow more slowly than revenue).

From the perspective of the geographical factor (GF), slight stickiness is observed for companies from all three selected countries in the pre-pandemic period. However, during and after the COVID-19 pandemic, the tendency towards cost stickiness among these three Central European countries begins to diverge, with Polish companies exhibiting the highest stickiness during this period.

The research has several limitations, including: (i) the research sample setting and data collection, (ii) the methodological approach to cost stickiness, and (iii) interpretation techniques. The research sample was determined based on Orbis Europe and consists of quantitative data. The chosen methodological approach is suitable for the application of univariate statistical methods. The limitations of this research lie in the chosen methods, which provide only static interpretation. Further research will focus on additional internal and external factors (qualitative and quantitative) influencing asymmetric cost behavior (cost stickiness).

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Innovation Potential for Business Process Outsourcing Service Centers: A Case Study of CEE Service Center Management

Ümit Güfte Peköz

Abstract Business process outsourcing (BPO) has proven to be a valuable solution for addressing business challenges, ensuring flexibility and agility. However, the growing average salaries in the CEE region and the developments in online collaborative technologies have enabled low-cost Far East countries to offer competitive service solutions to Western BPO customers. This study explores the innovation potential of establishing knowledge management (KM) practices in CEE BPO service centers, helping them ensure sustainable competitiveness in the global BPO market. The implementation methodology for this study is a single qualitative exploratory case study research design with embedded units. The study aims to discover how KM tools and methods are applied and accepted within CEE service center management for KM as an innovation and competitive advantage enabler. KM-oriented HRM strategies and practices have been found to motivate and encourage people to participate and contribute to knowledge sharing, identification, generation, capturing, enriching, reusing, and creating value.

Keywords Business process outsourcing · Knowledge management · Central and Eastern Europe · Innovation · Competitive advantage · Service centers · Human resource management

1 Introduction

In today's dynamic business environment, a company's agility and flexibility are crucial for its long-term competitiveness in the free market [16]. Business process outsourcing (BPO) has proven to be a valuable solution for addressing business challenges, ensuring flexibility and agility. It can be considered to have reached maturity at the beginning of the century. Over the last 20 years, the Central and

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Eastern Europe (CEE) region has increased its share in the BPO and Shared Service Center (SSC) market, with BPO centers and SSCs established in major cities across the region. India is the global leader, holding a 56% share of the BPO market, including SSCs.

CEE has a geographical and language advantage over India and other low-cost countries. However, the growing average salaries in the CEE region and the developments in online collaborative technologies have enabled low-cost far east countries to offer competitive service solutions to Western BPO customers. Previous cost advantages of CEE BPO service centers seem unsustainable as a competitive advantage, and center jobs are moving to Eastern countries. Therefore, the strategic question of how the CEE region can maintain its position in the BPO market by leveraging its competitive attributes against low-cost countries should be answered within the CEE region.

Companies must stay updated on market changes and advancements to protect their market share and explore expansion opportunities. Understanding market characteristics is key to remaining competitive against rivals. Identifying risks and threats early on can help companies establish their strategic positions and guide decision-making. Additionally, companies should aim to gain market share and prepare to adapt to potential market changes to sustain their competitiveness.

1.1 Literature Deficiencies

In BPO practices, two parties are usually involved—the client and the provider firm, with the client firm benefiting from the operational, process, and execution efficiency. The task of the low-cost provider is to secure these benefits through economies of scale and the implementation of standardized methods to simultaneously service many clients from low-cost countries. Many researchers identified knowledge generation and the learning organization structures as key success factors in outsourcing practices [16]. Through knowledge generation, companies can create and sustain new knowledge in their operations to create unique value propositions for their customers. Successfully applied KM can allow organizations to harvest innovative ideas and solutions to raise the barriers in their markets against competitors through which they can also enjoy a monopoly or stay competitive [40].

However, current research on KM for BPO practices concentrates on providing maximum benefit for the BPO customer. It needs to recognize the need for appropriate ways to maintain the providers' competitive position and establish an SCA (sustainable competitive advantage) through strategic KM in their area of operations. Knowledge sharing is an essential enabler in a new solution generation and can be a win–win situation for all parties involved in BPO practices. However, the question remains of how providers should identify which knowledge to incubate or retain and which to share or further cultivate with the customer.

1.2 The Purpose of the Study

This study explores the innovation potential of establishing KM practices in CEE BPO service centers, helping them ensure sustainable competitiveness in the global BPO market.

This study aims to serve everyone involved in CEE BPO service center operations, especially decision-makers and center management. The study findings should present the service centers' current KM practices and innovation potential.

The research intention is not to compare the service centers within the CEE region but to understand the current competitiveness factors and discover what KM practices are in place to secure sustainable competitive advantage.

1.3 Research Questions

This study aims to answer the following research questions to address the deficiencies presented above:

1. Where does CEE BPO service center management see its competitive position in the global BPO market, and how is this positioning reflected in strategic decision-making and planning?
2. What is the CEE BPO service center management awareness level for KM opportunities?
3. How do CEE BPO service centers apply their competitive positioning strategies to establish KM practices in their operations?
4. Which KM practices are established in CEE BPO service centers to facilitate innovation?

2 Methodology

The implemented methodology for this research is a single qualitative exploratory case study with embedded units. Consequently, a qualitative case study research design is chosen, as the study's primary purpose is to find out how KM tools and methodologies are applied and accepted in CEE BPO service centers. The main reason for favoring qualitative research is that, through quantitative and questionnaire-based surveys, it is impossible to detect the context and meaning of personal experience that a person had with a KM in her/his area of operations. This study investigates the awareness level within CEE BPO service center management for KM as an innovation and competitive advantage enabler.

For the data collection, the episodic interview method is chosen [15], as this interview method should deliver essential information about the usage experience of KM tools in daily operations. The episodic interview method delivers the findings

by challenging the responses through the simultaneous integration of episodic and semantic levels. The combination of thematic analysis and system analysis is chosen to be an appropriate analytic method [20], which corresponds with the chosen data collection method [2]. This combination makes it possible to investigate the complex social systems and process dynamics, which also makes it appropriate to answer the research question of this study about the usage practices of KM to support innovation activities in CEE BPO service centers.

Bratislava was chosen to represent the CEE region due to similarities in infrastructure, employee profiles, educational level of employees, wages, and other demographic characteristics. It is planned to run 40–50-min interviews with volunteer center managers and operational leaders in different BPO service centers in Bratislava. The participants' identities and the organizations' names will not be recorded or documented in any way in this research, and names will be anonymized from interview transcripts. The aim is to secure business confidentiality to protect organizations against strategic exposures.

2.1 Business Challenges and Theories

CEE has established itself in the last two decades as a hub region for shared service center operations and BPO centers. This was especially evident after the removal of the Iron Curtain when significant differences in salary structures in this region compared to Western Europe became relevant. BPO and service center operations found fertile ground in these countries because of many factors, such as a highly educated population a low-cost infrastructure, and a short geographical distance from outsourcing firms [29, 30]. In this stagnated industry and production-oriented market environment, the human resource-intensive service industry seemed to be a solution to make economies grow again [25]. "These centers are important employers of young people with year-on-year headcount growth rate up to 10%." [29]. When the average salary increases are observed over the last two decades, it is evident that CEE countries are showing progress in developing their economies.

In regional cities, particularly those in Central and Eastern Europe, the rise of BPO (Business Process Outsourcing) has put pressure on talent availability due to migration to Western economies and low birth rates. The government's ability to address migration and birth rates will significantly impact future talent availability and salary inflation.

The challenge in this region is that what once seemed to be a competitive advantage can turn into a self-destructive development since client firms will probably look for new opportunities in low-cost countries in another part of the world or regions once initial cost advantages diminish because of the increasing employment costs [29, 33]. CEE BPO and service centers need to reconsider their strategies, as every organization and firm plans strategically to ensure that it can provide differentiated value to its customers from its competitors to stay competitive.

In literature, competitive advantage is defined as the ability to create unique customer value through resources that a company possesses or has access to. Its competitors or other firms must refrain from duplicating or substituting these capabilities. Another way to look at competitive advantage is that it can be achieved by implementing a strategy at a time when no other firm can apply the same strategy or by applying the same approach as competitors but in a superior way, resulting in customer experience with goods or services that are hard to imitate.

If a company can achieve and maintain a leadership position over an extended period and can ensure that current and future competitors cannot replicate its strategy, then such a competitive advantage can be considered sustainable. The scientists further define which resources can be considered as a source of competitiveness to secure sustainable competitive advantage (SCA) and their characteristics. These resources must be valuable, rare in a given industry or environment, and difficult for current or potential competitors to obtain. Furthermore, they should be difficult to imitate or copy, and no substitute exists for these resources or skills. If resources and skills are accumulated in the company [27, 36] that directly contribute to value creation, these same resources are not available to competitors. Competitors cannot imitate these resources or bring substitute resources together to execute similar strategies aimed at satisfying customer needs; then, these resources can be considered a source of SCA. A disruptive innovation can lead to new developments in a given industry, causing what was once regarded as rare and valuable to lose its value and be seen as a disadvantage. In such cases, an SCA is not destroyed by competitors through imitation but rather by unexpected changes in technologies or solutions.

Company resources are to be identified as critical if they can contribute to value creation for a customer and if they can be used in creating a superior (unique) customer value or can be used in providing a lower-cost solution. In literature, it is reported that sources of SCA are divided into two groups, the first being unique assets and the second being unique (distinctive) skills or capabilities. These sources let a firm realize superior customer value through differentiated products or services, and they are also essential for being a cost leader in a given market. Bearing this in mind, strategic decision-makers need to identify first whether they see themselves in a given market as a cost leader or as a quality leader, and according to this decision, identify which resources can be seen as sources of an SCA.

Imitation of competitive advantage practices and resources is important to protect market position. Tacit knowledge is found to be difficult to imitate and, accordingly, can make it hard for CEE centers to imitate SCA. It is, therefore, essential to find out how the CEE BPO service centers' management considers tacit knowledge preservation through employee retention since tacit knowledge resides within the human mind [23].

Characteristics of BPO Services

The literature identifies services as intangible, heterogeneous, inseparable, and imperishable. Service is intangible and inseparable from the customer and rendered simultaneously. It is heterogeneous and perishable, meaning this intangible performance happens at a certain time, and it is impossible to store or postpone the delivery

of this performance [25]. Discussing the evolving service characteristics is out of this work's scope and requires separate research.

However, this research should differentiate between the characteristics of resources used in manufacturing and the service industry since technological and manufacturing competitiveness differs from service industry competitiveness. Under the service definitions and examples, it makes sense to regard BPO CEE centers as operating in a service industry by providing services to their clients [25].

BPO service is tangible even if tangible goods and technologies are involved, and although the transformation of the customer's resources is tangible, the service performance itself is intangible. Furthermore, the resources of a provider can be considered non-heterogeneous, which defines how different and diverse characteristics can be identified in a given resource bundle. But on the other hand, the heterogeneity of customers' resources is seen in services. The inseparability of service rendering action from the simultaneous presence of the supplier and the receiver of services is considered a key characteristic of a service definition.

Due to advancements in information technologies and new cloud solutions, it can be questioned if BPO services can be considered inseparable from customers' sources since a solution can be transferred to a customer at any time as customers become available. This challenge, especially cloud technology, with a one-to-many solution architecture, brings new possibilities. It can be further considered that BPO services are perishable if it is seen as being human resources intensive and service is provided at a point in time. If the service delivery point in time is postponed and missed, all resources collected and organized can be counted as lost, since they missed the opportunity to create a value-add [25]. When BPO is considered and regarded as a service rendering, it is furthermore necessary to highlight the characteristics of BPO solution provision in service centers. This is explained in detail in the coming section.

3 Sources of Competitiveness in Service Centers

Service provision is analyzed and described in two ways [31]. The first way is the complexity, the steps, and sequence involved in provision, and the second way is the execution width and the variations involved in service delivery. These two classification measurement factors are called the complexity and the divergence of a service (process).

We can assess the complexity of a service by examining the number and intricacy of the steps involved in performing it. For instance, accounting is more complex than bookkeeping because it entails a more elaborate process with more functions and steps. A highly divergent service would involve unique performances for virtually every process, while a service of low divergence would be largely standardized [31].

This identification is important in strategically positioning a firm (CEE BPO service center) in a global BPO market. In strategy development, a CEE BPO service

center should follow either cost leadership through economy-of-scale and standardized services or quality leadership through service differentiation and customization [29].

In this context, it can be worthwhile to conduct a separate study on the main-stream motivation in the global BPO market and find out if BPO customers are interested in high-value or low-cost solutions. After this identification, the next challenge for the CEE BPO service providers can be to see if they can move their customers into a quality (high-value) quadrant or if the customer will abandon the center long before the service provider has a chance to demonstrate their capabilities and to provide the solutions.

In the light of this context, where high complexity and latitude in solutions are involved in gaining competitive advantage in the BPO and service center market, a question can be proposed to guide this research further:

Which resources or capabilities can be identified as a source of SCA in CEE BPO service centers?

3.1 Innovation as a Source of Sustainable Competitive Advantage (SCA)

The potential of innovation as a source of competitiveness for CEE BPO service center providers can be explored to see if it suits service centers' search for a sustainable competitive advantage. Innovation is described in many ways reflecting the different business lines and the areas of interest [7, 21], but for this research, innovation represents product, process, and administrative innovation to bring new products and processes into the market, providing customers with innovative solutions resulting in a superior value-add.

It can be helpful further to identify innovation types presented in the literature, such as product, process, and administrative innovation. For this study, product and process innovation are relevant for CEE BPO service centers to consider in strategic planning. Product innovation represents not only new goods but also service solution creation. Process innovation includes documented process manuals or desk procedures and undocumented, incorporated practices and routines within an organization.

Innovation encompasses the implementation of discoveries and inventions and the process by which new products, systems, or processes are developed. Innovation in services and solution design can help organizations exploit their resources to generate competitive advantage, resulting in SCA. Companies and organizations, through innovation, can find new opportunities and even create new markets to enjoy SCA. In this context, innovation is regarded as a key component of a strategic design in finding new solutions and bringing them into the market. Innovation and innovativeness can help organizations and firms develop new products that other competitors cannot provide, either similar or imitated, in the same market. These new market conditions

will let an innovative company perform better, not only in meeting customer needs but also in financial measures.

The literature shows that it is difficult to identify a direct linkage between innovation and the firm's performance since the performance measurement is difficult [22]. In research, it needs to be identified clearly if a study is to measure a financial performance, a social performance, or a quality performance of a firm in question. Naas et al. [26] reported the problem of defining how to measure the effects of innovation on a firm's performance or profitability related to the innovation activities of a firm since it is a challenge to get reliable data apart from published financial data [26]. Furthermore, the period of measurements can vary depending on the firm's industry in question.

Furthermore, Naas et al. [26] reported that innovation requires an investment and can be a cost-intensive activity. In their study, they surveyed production companies, and it is questionable if their findings are also applicable to the service industry. Still, the idea here is to show the difficulties in innovation performance measurement only [26]. According to their study, innovation activity is cost-intensive, and this cost must be reflected in production costs. This leads to the conclusion that innovating firms cannot always be profitable in their sales activities, but if they are more dynamic in addressing the market challenges, it will be easier for them to grow once an opportunity arises. In their work, it is seen that by being innovative, a firm can create temporary monopolies and gain an opportunity to sell new products either at a higher price than competitors or more products at a lower price. This will result either in an increase of revenue or an increase in market share. In both cases, they will grow relative to the market, but this will not necessarily be reflected in financial performance indicators. In the short term, the innovation activity will probably result in the growth of performance rather than higher net profit [26].

3.2 Knowledge Management (KM) as an Innovation Enabler

It is further worthwhile to study how a firm or organization can become innovative, and which resources are needed for innovation. Similar managerial questions are reviewed in literature and studied also through systematic research, and some findings are showing that knowledge is an important organizational resource in innovation management [13, 14], and it should be managed as a critical asset of an organization just like any other tangible asset [3, 24].

In a paper in 2001, Bhatt considered data as raw facts, information as organized data, and knowledge as meanings of information [6]. The paper showed that the relationship and connections between data, information and knowledge exist in a recursive fashion. Information is derived from the data mass and the difference is in the organization of data sets. Knowledge is differentiated from information though personal or situational based interpretation.

Knowledge can be characterized as meanings, which individuals can extract from information, combined with an experience or in a context to reflect on their

handling. Information can be seen as data being furnished or equipped with a relevance and purpose. Some authors consider knowledge as a firm's capability. Knowledge management (KM) in this context is a potential innovation enabler managerial tool to facilitate creative activities to bring new ideas and practices into light. Collaboration with a client is an example to enrich hands-on knowledge together, so that a firm can create new innovative solutions. These novel solutions can in turn serve the clients as well as being competitive in their markets [22]. KM is to be regarded as an innovation enabler in organizations, which support knowledge identification, generation, cultivation or enriching, and further reapplication of new knowledge into problem solving and diffusion within the organization [8]. Only through creativity and efficient reorganization of organizational knowledge can a firm create unique capabilities, which can serve its competitiveness. Tacit knowledge is considered as a source of innovation, as it is the core element in creating new, previously unknown solutions and products.

The process of innovation relies significantly on knowledge, as knowledge encompasses more than just data, information, and conventional logic. Its power stems from its subjectivity, underlying values, and the assumptions that drive the learning process.

Knowledge is a scarce source of innovation and organizations should try to protect this intangible asset even in their strategic partnerships. For more important innovation initiatives, they should refrain from getting external consultancy and rather develop internal capabilities to manage the innovation. This protectionism may be considered as an obstacle in developing ideas and innovation, since acquisition or imitation is also considered to be a source of innovation, which should be supported by an absorptive capacity of an organization, to be able to learn and cultivate the knowledge coming from external partners or competitors.

Through knowledge management (KM) practices, companies can generate and maintain new knowledge within their operations to create a unique value proposition for their customers. This can help their customers gain a competitive advantage over their rivals. Access to new knowledge enables organizations to cultivate innovative ideas and solutions, strengthening their position in the market against competitors, and potentially achieving a monopoly or sustaining competitiveness for a certain period of time.

The innovation performance of a firm is found to be positively affected by successfully executed KM practices and applied strategies, as empirically confirmed in another study. This innovation performance is possible in a firm, where KM is integrated with their competencies and capabilities as a critical element in designing and applying their strategies. At the same time, they reflect the organizational learning to redesign and to update their strategies in reaching SCA. These findings confirm that the knowledge resources of an organization are of strategic importance in securing SCA through innovation.

It can seem surprising that according to the study, Lesson-Learned mechanisms are found not to be facilitating factors in innovative solutions creation in their surveyed organizations. The reasons for this negative relation is that re-usage of existing

knowledge in product design can lead to generating a product with existing or old-fashion technologies. Such products may not necessarily address the current customer needs and other competitors might be ahead in technology, or process adaptation, thus enabling them to provide new products or solutions. In their study learning mechanism is understood as knowledge transfer and re-usage for explicit knowledge through lessons learned information databases, and mentoring or on the job training with senior member and new comers to enable the tacit knowledge transfer. This finding is discussed also in a previously run study, where out-of-date knowledge and technologies can result in innovation failure in applicability.

The objectives of KM are to help the organization be intelligent in its handling of knowledge to sustain viable and continuous success. At the same time, it should help the organization to realize and bring the best possible value-add out of its resources. According to Wiig is a managerial tool to focus on strategies for a firm in an effective way: first through monitoring and enabling knowledge generation activities, second through establishing and attending the knowledge infrastructure, third through rebuilding, reorganizing and updating its knowledge assets, and finally through further exploiting and applying identified knowledge to generate value-add.

> Empirical evidence supports the view that a firm with a knowledge management capability will use resources more efficiently and so will be more innovative and perform better. [11]

An alternative way of viewing knowledge management is to consider it as a coordinating mechanism that enables resources to be converted into capabilities. As scientists attest, coordinating mechanisms are required to ensure people not only know their own jobs but are also able to interpret and respond to information, flowing in to the organization [11].

KM influences organizational performance through an effective framework or systematic approach to applying their innovation strategies to get results in growth or financial terms, and it is found to be an effective tool to create an impact on the innovation performance. In their research, identified ten types of KM practices to list KM activities in an organized way. These are listed below. This list is not complete as Heisig [19] compared more than 160 KM frameworks to form a generalized and consolidated list of KM around the globe in different industries and regions [19]. But it was not possible to reach a general standard knowledge management framework, since every KM process or practice is found to reflect organizational needs in a given context. Scientists also defined KM practices as management activities to improve organization of knowledge resources to produce effective solutions in organizations, and deliver value out of the knowledge assets.

It is also worth mentioning KM tools and processes organized in a new research. This categorization of KM tools and practices can guide us in identifying the state-of-the-art KM tools in the field. Even if there are more research studies and literature on hand, this paper can be taken as representative of the state of the KM, by being an actual study in KM field, but not an exhaustive complete list. A full list of classification of KM tools and practices is given in Table 2 adopted from a study. This table gives a detailed overview of KM tools application examples. In the first part of Table 2 the KM toolkits and tools to manage knowledge resources are listed. They

represent the knowledge strategy, creation, retention and measurement (evaluation) tools. In the second part the same table, the KM tools to manage knowledge flows and enablers are listed. These KM tools or toolkits help in knowledge sharing, usage, acquisition and preservation.

3.3 KM and Knowledge Capital for a Learning and Innovative Organization

KM can be identified as being a process to acquire needed knowledge, disseminate this knowledge and to use or apply this knowledge to respond to customers' requests [11]. KM strategy should strive to fill in the gap between the on-hand knowledge asset of a firm and identified future need for these resources. In strategic management KM is to be handled as a tool to assess current knowledge requirements and compare them with on-hand identified in-house knowledge assets, to clearly see where a firm should focus to gain needed knowledge capital [6].

An identified knowledge gap can be closed through several acquisition approaches. This can be through learning of existing employees, hiring and acquiring human resources which will reflect individual experience and skills, through contractual partnerships and relationships between suppliers or customers, or through licensing. Furthermore, this can be through proprietary agreements to gain access to new technologies [11]. In this context BPO can be regarded as a good example for SME organizations or for established companies to access needed knowledge assets, like expertise and experience through such contractual relationships. If specialized knowledge is needed for the knowledge absorption then bringing people with such specialist knowledge should be considered cited by Windsperge [37].

KM activities should also support organizations in cultivating their most scarce and valuable assets, including their knowledge base, to be able to bring the high value-add activities into business focus. KM can further help organizations design knowledge based strategies, and make strategic decisions to facilitate knowledge assets allocation and usage.

According to Bhatt in 2001, KM consists of processes, which can be grouped under knowledge creation, knowledge validation, presentation, distribution and application process [6]. Furthermore, KM is "the process that creates or locates knowledge and manages the dissemination and use of knowledge within and between organizations." [11].

There are many different derivatives of these groupings but for this research the process classification found above is identified to be suitable, since the aim of this research is to determine which main KM activities and processes are in place in CEE BPO service centers. If during the research any additional activity is identified, which cannot be classified under these main groups, this aggregated grouping can be visited once more for a clarification.

Another definition by Bhatt [6] highlighted the importance of human resources in knowledge generation, and suggests KM facilitates knowledge processes and flows:

> The conversion between data and information is efficiently handled through information technologies, but IT is a poor substitute for converting information into knowledge. The conversion between information and knowledge is best accomplished through social actors, but social actors are slow in converting data to information. [6]

Similar guidance is provided by other sources. KM is applied mainly through two dimensional practices, one through technological solutions and ICT, and in the other through personal practices. Hansen, Nohria and Tierney in 1999 saw KM as being applied in ICT through data capture, storage, organization and reuse, and in HRM processes, typically through hiring, training and rewarding (remuneration). Bhatt [6] saw both technological and social environment equally important in successfully applying KM processes and suggested having an optimized balance between these systems [6]. The very same view was presented. Tacit and codified knowledge are two sides of the same coin. You need one to use the other. This distinction is important in defining the KM toolkits that help manage knowledge resources.

For clarification, this classification of KM approaches or systems can be followed. The technological approach of KM focuses on codifying and capturing the data, to convert an explicit knowledge into an organized data. This should be achieved by rewarding people on the base of their contributions to delivering and using the data. The personalization or socialization approach of KM tries on the other hand to bring people together and let them socialize so that they can share and learn tacit knowledge from each other.

These two approaches are named as a codification strategy and a personalization strategy. Codification strategy is seen to be applied through ICT resources and practices, and personalization strategy is found to be applied through HRM based practices and tools. In ICT focused approaches the aim is to develop and deploy applications and platforms to facilitate coded knowledge sharing and contribution in new knowledge generation. The HRM oriented KM approach focuses on finding un-codified personal knowledge from individuals to generate organizational knowledge, which can take place in different forms and practices. A product view suggests that knowledge resources can be located and processed as a separate subject to the person within the organization, and the process view regards the knowledge to be handled within the social interactions. In the process view the knowledge stays with a person and is cultivated through person-to-person contact.

In section XXX 10 the application implication of HRM based practices (process view) will be explained in more detail to support the idea that knowledge performance indicator based compensation models can help to motivate employees in participating and contributing for knowledge generation or knowledge enriching.

4 Knowledge Types and Scholars Considerations

The reviewed literature illustrates that knowledge can be classified as being tacit and explicit, where tacit knowledge represents personal knowledge in un-codified and implicit state [32], whereas explicit knowledge is codified, and the knowledge is in a transferable state and can be easily shared in formal and semantic way with a lowest information richness between parties [37]. Both tacit and explicit (codified) knowledge management are found to be critical in an organization, since both knowledge types should be well understood in KM tools design and application, with an aim to create value-add. Carneiro [8] pointed out that some knowledge is written down and codified, which represent explicit knowledge, and some knowledge can be transferred or learned only tacitly (implicit) through practice [8]. The success of technological modifications (incremental innovations) are dependent on both knowledge types. Transferability of knowledge is another critical attribute to determine the organizational capacity for SCA. Scientists identified the main differences between knowledge types, as being tacit (implicit and subjective, knowing how, procedural) and as being explicit (objective, knowing about data and theories, declarative). Tacit knowledge is difficult to transfer since codification is not possible. Only through practice and application can such knowledge be shared with others. Tacit knowledge transfer is often found to be costly and not always efficient.

It is relevant here to understand the following characteristics of knowledge as listed to see what factors or practices might help organizations to manage their knowledge flows.

Capacity for aggregation is an enabler for knowledge transfer, since organizational absorptive capacity is needed here for knowledge acquisition. The appropriability characteristic of knowledge indicates if a resource owner receives a return to compensate its cost. Tacit knowledge is found to be not appropriable in most cases where direct transfer is not possible, but is only transferred through applications in product or services generation. Specialization in knowledge acquisition is required, as organizations need specialists in a given field to create, acquire and store the new knowledge, otherwise knowledge transfer cannot happen efficiently.

The knowledge requirements of production can be seen by the following. Value creation requires input and outputs, and knowledge is seen as a primary critical resource in this creation, as human resources have a value depending on their knowledge and technological solutions are an embodiment of knowledge.

Carneiro [8] pointed out that some knowledge of the usage of technologies or process are written down and codified, and this represents explicit knowledge while some knowledge can be transferred or learned only tacitly (implicit) through practice [8]. The success of technological modifications (incremental innovations) are dependent on both knowledge types. Another taxonomy to classify knowledge was presented by Winter [38] through four dimensions, "tacit/articulable," "observable/not observable in use," "complex/simple," and "dependent/independent of a system."

[38]. These and similar views try to evaluate knowledge on the base of its characteristics, and only through good understanding of knowledge attributes can it be possible to design KM tools and systems.

The importance of tacit knowledge is highlighted in many studies, as a clear explanation of innovation process is not an easy task to accomplish.

> Tacit knowledge lies below the surface of conscious thought and is accumulated through a lifetime of experience, experimentation, perception, and learning by doing. Managers who can tap into this vast pool of creative energy can elevate the innovative capabilities of their teams well beyond the incremental. [23, p. 182]

4.1 Activity Model to Uncover Tacit Knowledge

In the literature the SECI (Socialization Externalization Combination Internalization) model is acknowledged as the best-known KM tool to help organizations convert tacit knowledge into explicit knowledge through socialization and internalization [5, 9, 17]. SECI stands for a socialization, externalization, combination, and internationalization of tacit knowledge. The SECI model is meant to be applied in a circle, as it is a continuous process or practice.

- In the first phase (Socialization) knowledge sharing takes place between involved parties through socialization, being involved in an activity like seminars or workshops together, or even on the job training with an experience person to share and learn the tacit knowledge from each other. This represents the tacit to tacit knowledge exchange or sharing by actively spending time together.
- In the second phase (Externalization) externalization takes place through creating draft plans for the seminar or workshop, documenting the training process or expressing the experience or the outcome of the socialization event. Tacit knowledge is in a way externalized through sharing with others.
- In the third phase (Combination) these externalized and explicit knowledge from all parties are combined and reapplied to create new knowledge. Once the knowledge is externalized, it can be documented and codified in data repositories as a process handbook, for instance, and can be distributed throughout the organization.
- In the last phase (Internalization) the codified explicit knowledge can be applied further, to be internalized by an individual. This phase will not happen automatically and an effort here is needed from an organization to give a person some incentive to reapply identified explicit knowledge, or learn from this experience to create new knowledge, which will stay with the person and become tacit knowledge.

The SECI model is found to represent the challenges in tacit knowledge capturing and externalization, since the socialization phase is regarded as being time consuming and not always effective, and participating group members should further show an interest in sharing their tacit knowledge and experiences with others. Even if the

organization manages to capture tacit knowledge, the tacit knowledge transferability depends on the knowledge attributes, which determines the transfer methodologies.

4.2 Information Richness and Knowledge Attributes

Windsperger [37] presented a framework of a franchise practice in two dimensions for transferring firm knowledge and capabilities between franchise partners [37]. The information richness dependent communication mechanisms and knowledge attributes underline the knowledge transfer challenges in franchising partnerships. Their findings show that choosing communication mechanisms in a franchise practice is dependent on the knowledge attributes "Codifiability", "Teachability", and "Complexity", which they determined from the empirical research conducted and the previously identified knowledge and capabilities attributes framework by Winter. The idea in their work is to demonstrate these knowledge attributes, which help us in defining the tacitness of a knowledge to be shared or distributed.

According to their work, Windsperger [37], knowledge and the firm capability attributes can be explained as the following:

"Codifiability" defines how much is possible to codify and explicitly represent a knowledge, which effect the difficulty level in transferring this knowledge. This transfer can take place between firms, groups or individuals within a firm. If codifiability is found to be low, then the knowledge is found to be more tacit and implicit.

"Teachability" defines how easy or difficult for a person to teach her/his tacit knowledge and experience to a new person through training or workshops, even if this knowledge is not explicitly or formally articulated.

"Complexity" is a challenging attribute to clearly define as it consists of several dimensions, from technical, distinctive skills to specific capabilities, including practices. If knowledge is identified to be highly complex, then it will be difficult to transfer and share this knowledge and it can be considered to be high-tacit knowledge.

In their study Windsperger [37] further examined how the identified knowledge attributes determine the tacitness of a firm's knowledge to be shared, and what effect this identification has on the chosen communication mechanism between franchise partners [37]. The choice of a communication mechanism has an effect in return on the information richness, which is again important for the communication of the knowledge in transfer. They reflected in their work on the model previously developed by Daft and Lengel [10], where in this previous model the communication medium choice is made or defined on the base of the information richness required [10, 28, 37]. This varies from the poor content communication medias like formal, numerical guidelines or user manuals to more information-rich content communication possibilities like face-to face meetings or workshops. The very same is true the other way round, that the communication medium choice also effects the information richness to be communicated. Scientists demonstrated in a study that the firm's performance is also dependent, in complex environments and markets, on the

media richness of a firm's communication. The codifiability and the teachability of knowledge (capabilities) determine at what speed it can be transferred. This has a direct influence on knowledge sharing and diffusion and is considered to influence the media choice.

A further important factor in knowledge sharing is trust, which can facilitate communication between partners even if such communication protocol is not clearly defined at the beginning in franchise contracts [37]. Trust is considered to overcome communication difficulties even if a clear framework is not defined in franchise contracts and agreements, or the required communication channel is not in place. Accordingly, trust can ease the knowledge sharing between communication partners. These findings can be reflected in BPO practices where knowledge sharing and creation is identified as important success factors.

Trust is again important in sharing tacit (sticky) knowledge through face-to-face interactions, or sharing on the job personal experience, even if this type of knowledge transfer is seen as cost intensive and time-consuming [37].

4.3 KM Tools Applicability Challenges and Establishing Practices

Many researchers identified knowledge generation and the learning organization structures as key success factors also in outsourcing practices. One way to help organizations in knowledge generation is to practice a lesson-learned approach where new collaboration platforms and virtual team rooms can be deployed to facilitate team members' contribution to new knowledge generation or to enrich existing knowledge [40].

In literature the ICT (Information and Communication Technologies) based KM practices are also seen to be key factors effecting the firm's innovative performance resulting in an SCA. In a study, ICT (Information and Communication Technology) is identified as an enabler in KM through facilitating collaboration, communication, information availability, simultaneous learning, application in prognosis and analyses of business data [4]. The findings of both studies are supported by empirical evidence in the study where KM practices aligned with ICT strategy is found to be supportive in achieving high firm performance, as well as for being innovative. In all the above mentioned studies the importance of HRM practices in KM strategy and tools application is further highlighted.

As a criticism, in their conclusion supported the idea that ICT applications and deployment can make a difference in innovation performance of a firm, and further they suggested that ICT can help open-innovation, since data availability, organization and information analyzing is possible through ICT. ICT can furthermore help organizations to exchange knowledge and information on a common collaboration platform. But the findings are considered that tacit and sticky knowledge is important in defining the innovation potential of an individual [34], it can be questionable how

ICT tools, designed to handle (un)-structured explicit data, can help in tacit knowledge transfer and lead to collaboration in innovation creation. This criticism can support the KM strategy aligned HRM practices importance in achieving innovation performance.

A further example was given in a study reported, highlighting the importance of both approaches to manage the knowledge assets of a firm, where they named these approaches the IT paradigm and the humanist paradigm. The IT paradigm handles explicit and tangible knowledge, with an aim to identify, capture, organize and reuse this knowledge in the organization. The humanist paradigm on the other hand supports organizational learning through personal interactions, even if the knowledge is not identifiable beforehand and is found to be open for interpretive explanations. In an IT oriented paradigm, the focus is to analyze how explicit knowledge is handled through ICT systems [1]. As a result of this approach organizations are seen to be a knowledge information processing systems. In an HRM (humanistic) approach, the focus is socialization within the organization to identify, capture and share tacit knowledge. This tacit knowledge was previously not known to exist, but was applied without awareness in providing solutions. This is in line with the tacit (intangible) knowledge acquisition, or internalization as presented in the SECI model.

Scientists explored further what links and relationships exist between KM and innovation performance within the organization. The main finding of their study is that the HMR focused approach is more suitable for manufacturing companies to create innovative new products, but at the same time the application of an HRM and IT focused KM approach is significantly important. These findings are in line with the previous study and literature, where tacit knowledge is found to be important in innovation [8]. Their conclusion shows that both the IT and HRM focused KM approaches are valid for an innovation performance and there is a positive correlation between balanced application of IT and HRM focused KM systems and tools. Scientists confirmed the integrated KM approach of both the ICT and HRM view.

4.4 Importance of Social Context in KM for Innovation

Tacit knowledge is regarded as a source of innovation, by residing in peoples' heads, experience and habits. And since new product and services development is highly dependent on creativity and the process of exploration, it is important to facilitate knowledge transfer and sharing within an organization [23]. In another study the importance of tacit knowledge transfer in the innovation process is analyzed, and findings support the view that collaboration for team members and internal communication systems are critical in supporting the tacit knowledge flow within the organization.

In literature there is also a criticism to KM for tacit knowledge. A critical review of literature presents three key arguments why KM cannot support capturing tacit knowledge and the management of knowledge sources. The first argument is that

tacit knowledge stays with a person and cannot be separated and managed by the firm or it is not possible to capture, store and share tacit knowledge. Secondly it is a challenge to apply KM in practice since often the necessary commitment and strategy is not in place to overcome barriers, like cultural fit or systematic approach failures. Thirdly empirical evidence is hard to measure to prove a direct linkage between KM and a firm's performance.

Following his study over a five-year period, reported on his research into how acceptance of KM applications takes place within an organization. Massingham tried to measure the contribution of KM to the firm's performance. In this study he tried to address the above listed criticisms:

- if it is possible to apply an objective measurement of KM practices, to empirically support that KM has influence on an organizations performance;
- if a KM strategy is applicable to support the KM strategy view;
- if the KM practices can be applied systematically to overcome acceptance barriers.

Scientists presented KM in two dimensions (Table 1): the first dimension is managing the firm resources and the second dimension is managing the knowledge flows though enablers.

The first dimension, the knowledge resources management (product view) is presented in four set of KM toolkits, under the knowledge strategy, creation, retention and measurement:

- Strategy: Identifying the firm's strengths and weakness to compensate for knowledge gaps,
- Creativity: Enrich on-hand knowledge resources
- Retention: Protect the company position within the market
- Benchmarking and measurement: compare own capabilities with the best-of- class KM practices.

The second dimension, the knowledge flow management (process view) is presented in four sets of KM toolkits, under knowledge sharing, acquisition, usage and preservation:

- Sharing: Enabling knowledge flow through social communication between sender (who knows) and receivers (who should learn).
- Usage: On the job application of tacit knowledge through mentoring, training or sharing previous experience.

Table 1 Current KM tools and practices in managing organizational knowledge assets

KM toolkits and tools to manage knowledge resources (product view)	KM toolkits and tools to manage knowledge flows and enablers (process view)
Toolkit 1: knowledge strategy	Toolkit 1: knowledge sharing
Toolkit 2: knowledge creation	Toolkit 2: knowledge usage
Toolkit 3: knowledge retention	Toolkit 3: knowledge acquisition
Toolkit 4: knowledge measurement	Toolkit 4: knowledge preservation

Table 2 Classification of KM tools and practices

KM toolkits and tools to manage knowledge resources (product view)
Toolkit 1: knowledge strategy • Competency mapping: Competency gap analysis • Future capability requirements: Identifying necessary capabilities and dis-aggregating capabilities into types of knowledge resources • Sourcing decision: Acquisition or internal creation of the needed knowledge
Toolkit 2: knowledge creation • Creative abrasion: Brainstorming technique to encourage idea generation • Parallel thinking: Brainstorming technique through six thinking hats methods • SECI Model: Four step of tacit knowledge internalization • Expert teams: A process of managing teams to reach their targets • Double-loop learning: Challenges the team to encourage cultural change and organizational learning
Toolkit 3: knowledge retention • Exit interviewing: Aim is to uncover tacit knowledge, but barely successful • Mind maps: Encourage teams to apply tacit knowledge to designated problems • Videotaping: Interview and situations recorded to reflect participants experience for a given subject or situation • Mentoring: Transfer of experience between senior and junior employees though social interaction • Strategic action framework: "career development/succession planning programs, phased retirement programs, knowledge recruiting processes and mapping competencies to career continuums"
Toolkit 4: knowledge measurement: • Knowledge valuation: Value of a persons knowledge for the organization • Cultural change metrics: Necessary behaviors and attitudes for a learning organization and to prevent knowledge loss • Risk management: Allocating a risk score to knowledge resources to identify critical elements

(continued)

Table 2 (continued)

KM toolkits and tools to manage knowledge flows and enablers (process view)
Toolkit 1: knowledge sharing • Knowledge sharing barriers: Identify and understand the nature of the transfer problems • Cultural change: Linking Self-awareness of a person to needed learning behavior and attitudes in the organization • Communities of practice: Forming groups with like-minded people to facilitate knowledge exchange, with an aim to capture and share it further • Motivation: Locate what drives people to refrain from sharing the knowledge and hot to overcome behaviors • Communication skills: Facilitate and cultivate the communication ways and techniques – Narratives: Sender techniques – Storytelling: Sender techniques – Conversation: Sender techniques – Listening: Receiver techniques – Appreciation: Receiver techniques • Understanding the gap between the knower (sender) and seeker (receiver): Knowledge stickiness and finding the balance between knowledge level of both sender and receiver
Toolkit 2: knowledge usage • Knowing doing gap: Discussing the barriers in using a knowledge • Peer assists: Through experience sharing new comer start a project at a higher point in a learning curve • After action reviews: Review of an action while happening and to learn from current experience • Retrospects: Learn from others experience and document the lessons learnt
Toolkit 3: knowledge acquisition • Human resource accounting model: Effect of an external knowledge transfer with in the organization • Acquisition barriers: Barriers to external knowledge acquisition market efficiency: External knowledge identification and cost calculation for the internalization • Contract specification: Identifying the right knowledge and the channels to manage the external knowledge • Knowledge brokers: Knowledge translation to apply in different part of an organization
Toolkit 4: knowledge preservation • Select process: Classification of knowledge to keep and cultivate or to capture organization memory • Storage: Capture and make available for access as needed • Metadata: It is a data about data to make data collections identifiable in searchs • Lessons learned database: Capture and save best practices

- Acquisition: Internal and external knowledge identification and learning, or hiring to bring an external knowledge person in to the organization.
- Preservation: Tacit knowledge internalization through individuals, collective reapplication to facilitate the access to knowledge.

Bhatt [6] also defined KM as a process to create, validate, present, distribute and apply, but the main contribution of the research study reported is to integrate KM with strategic management at the same priority [6]. The KM toolkits presented in the Massingham formation can be also regarded as being a reflection of KM practices or knowledge chain links as listed where they mentioned KM in seven steps:

1. Listing the existing knowledge, or evaluation of knowledge resources, which is presented under knowledge strategy.
2. Determining the required knowledge, or strategic analyzing, which is also presented under knowledge strategy.
3. Developing new knowledge, can also refer to acquisitions, and can be listed under both knowledge creation and acquisition.
4. Allocating new and existing knowledge, is knowledge diffusion and sharing.
5. Applying knowledge, which is very similar to knowledge usage.
6. Maintaining knowledge, which is similar to knowledge retention and continuous cultivation to enrich codified or organizational tacit knowledge.
7. Disposing of knowledge, can be identified with knowledge preservation.

In Table 2 classification of KM tools and practices are presented to give a consolidated broader overview. This will help to understand the research findings comparison with an aim to identify if similarities or contradicting practices in CEE BPO service centers can be observed. This kind of comparison can further help us to locate KM tools application barriers in the CEE BPO services field.

5 Key Factors in Applying KM Tools and Processes

5.1 Knowledge Activity-Based Compensation Model

KM should be seen neither only in a framework of ICT solutions and application practices nor in a framework of an HRM-centric phenomenon since the successful application of KM is dependent on the balanced application of KM in both frameworks. Only integrated and balanced KM practices can help organizations achieve their ambitions [6].

Scientists highlighted the findings that knowledge generation oriented HRM practices can positively influence and effect the innovation performance of a firm. This is achieved through better managing the KM practices based on knowledge based compensation models. KM oriented HRM strategies and practices are found to motivate and encourage people to participate and contribute in knowledge sharing, identification, generation, capturing and enriching.

According to their study, they further suggest that the compensation and incentive system should be based on direct knowledge performance indicators like knowledge creation, sharing, and utilization, and should replace conventional performance indicators like quantitative measurements of accomplished tasks or sales closed. With the help of new identified knowledge performance indicators. It can be easier to motivate employees for the organizations knowledge goals.

Scientists explored the relationships and linkages between HRM and KM practices to show that in a knowledge-oriented organization, different managerial strategies are required to facilitate KM practices than those found in non-knowledge-intensive

organizations. They highlighted that HRM is an important instrument in applying KM tools.

Four areas of HRM—training, decision-making, performance appraisal, and compensations or reward—should be linked with KM practices: knowledge acquisition, documentation, transfer, creation, and application. Their findings suggest that knowledge generation, sharing, and innovation should be seen as a base for compensation planning and remuneration. Through reorientation in HRM strategies organizations can better motivate employees to participate in KM activities. They further mention the importance of KM-based performance indicators in evaluating employee performance.

Mascitelli [23] presented another HR challenge in his study that it is a managerial task to ensure team member commitment in creating innovative new products since such product development requires not only tacit knowledge but the harnessing of this knowledge by team members for value creation. He further suggested that personal involvement and commitment from all team members is needed to have people applying their tacit knowledge in problem solving. After gaining emotional commitment and social interaction, either through person-to-object or person-to-person, hands-on experimentation should take place, to ignite or bring out the innovating potential of the team. Once such commitment level between the team members is achieved, further measures should be imposed to maintain high employee retention, and to provide a nurturing innovation environment, as well as to take risks like early prototyping or customer involvement in product developments [23].

5.2 Strategic KM Planning

Strategies to plan and implement knowledge-based activities are seen to affect a firm's innovation capacities positively. Knowledge-based strategy tries to assess current knowledge availability and identify future knowledge needs, with an aim to identify which knowledge gaps need to be compensated and through which channels. In this context, a knowledge-based strategy tries further to disseminate and increase the availability of knowledge throughout the organization. Consequently, KM strategies can help organizations achieve better innovation performance simply by clearly identifying strategic knowledge gaps and where to source needed new knowledge.

Strategic KM planning in organizations is also found to be an important factor in achieving successful deployment of KM tools and practices. In his study, he presented five KM-centered strategies, which are pursued by observed companies and organizations to best fit their organizational culture, strategic priorities, and value creation capabilities, including learning capabilities. Based on these synchronized capabilities and resources, organizations can create the most value out of their knowledge assets. Organizations follow the suitable combination of the five knowledge-based strategies listed below:

- Knowledge strategy as business strategy: It is similarly presented in Massingham's KM classification, and its focus is on knowledge creation, capture, organization, renewal, and sharing within the organization.
- Intellectual asset management strategy [35], focusing on structural knowledge asset management through explicit and codified knowledge. Patents, technologies, and processes are managed.
- Personal knowledge asset responsibility strategy, a focus on the personal knowledge capital of an individual to be applied within their operational area to create the most value out of given or available resources. This strategy can be effective in HRM view applications for KM tools and process deployments.
- A knowledge creation strategy focuses on letting employees apply their knowledge and capabilities to create new knowledge, innovate, or achieve competitive advantage [12, 16] through the capture of lessons learned.
- Knowledge transfer strategy, the aim of which is to make the knowledge available at the point of problem-solving, which can also be identified as in the Sticky knowledge approach [34], where the transfer is only possible through face-to-face interactions.

It is important for an organization to integrate both the technical and organizational (personal) views on KM strategy development to design and maintain a KM infrastructure that can facilitate and ease knowledge identification, capturing, preserving, and enriching, as well as reuse and creation of value. Further, it can be highlighted that even if an organization has the right KM infrastructure in place, it cannot ensure that the right investment decision or deployment strategy is in place since it is still a challenge to objectively measure KM performance. KM strategy should be translated into organizational, technical, or structural design to ease value creation from an organization's knowledge assets.

6 Conclusion

This study underscores the pivotal role of knowledge management (KM) in sustaining the competitiveness of Business Process Outsourcing (BPO) service centers in the Central and Eastern European (CEE) region. As the traditional cost advantages of CEE service centers wane due to rising wages and increased competition from lower-cost regions, leveraging KM practices has emerged as a crucial strategy for maintaining and enhancing competitive edge in the global BPO market.

The research highlights that effective KM practices, particularly those integrated with human resource management strategies [39], play a significant role in fostering innovation within CEE BPO service centers. These practices not only facilitate the identification, generation, and sharing of valuable knowledge but also enable organizations to transform this knowledge into strategic advantages. The findings demonstrate that KM practices in CEE BPO centers are instrumental in driving innovation and adapting to the evolving market demands.

By embedding KM tools and methodologies into their operations, CEE BPO service centers can enhance their capabilities, improve service delivery, and better meet the needs of their clients. The study reveals that a higher awareness of KM opportunities among management teams and the strategic application of KM practices can substantially contribute to the long-term sustainability and growth of these centers.

In conclusion, for CEE BPO service centers to sustain their competitive position in the global market, it is imperative to adopt and refine KM practices continually. The insights gained from this research offer valuable implications for decision-makers and practitioners in the BPO industry, guiding them towards more effective strategies for leveraging knowledge as a key driver of innovation and competitive advantage.

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Informatization and Data-Driven Democracy: Case Study of the Ukrainian Open Data Portal

Yuriy Syerov, Mariia Sokil, and Vitalina Horova

Abstract Before Russia invaded Ukraine, the country was one of the leaders in open data disclosure and development. According to the Open Data Maturity rating, Ukraine ranked sixth among all European countries in data openness last year. This position has a positive impact not only in the informational or legal sphere but also in the economy. The work of the Open Data Portal is one of the indicators that Ukraine continues to move in a positive direction of reforms and changes in all areas and directions. Accessibility and publication of open data make it possible to control the steps of the state, making corruption attempts impossible. The open data portal aims to provide information and communication in the field of open data and will help improve Ukraine's position in international anti-corruption rankings. The portal offers several opportunities for different user groups, including government agencies that manage data, IT professionals, business representatives, NGOs, the startup community, and ordinary users of the Open Data portal. Each group can benefit from the portal's services, making it a versatile tool for promoting transparency and accountability. The portal will be able to become the primary source of information and communications in open data. Government and nongovernmental organizations will use the Diia portal.

Keywords Open Data · Diia · Open Data Portal · Digital governance · Civic engagement · Transparency · Ukrainian digital transformation

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1 Introduction

In an era marked by unprecedented technological advancements, data utilization has become integral to the functioning of modern governments. The concept of Open Data [1], characterized by the transparent sharing of government information with the public, has emerged as a transformative force in promoting accountability, innovation, and citizen engagement. As nations strive to harness the potential of Open Data, Ukraine stands at the forefront with its groundbreaking Diia [2]. The open data portal is a key component of the broader Diia. Digital State initiative. The Diia epitomizes the Ukrainian government's commitment to digital transformation, with the Open Data portal being a strategic tool in this initiative. It is a pivotal platform for disseminating a wide array of government datasets, and its launch aligns with the Diia. The Digital State initiative represents a strategic endeavor to foster a more transparent, accountable, and citizen-centric governance model [3, 4]. Through this initiative, Ukraine aims to empower its citizens with access to valuable information, catalyze innovation, drive economic growth, and fortify the foundations of a knowledge-based society.

This scientific paper endeavors to delve into the multifaceted impact of the Diia. Open Data portal on Ukrainian governance, exploring its inception, evolution, and transformative potential. By examining the portal's architecture, the types of data available, and the mechanisms employed to ensure data quality and security [5, 6], we aim to provide a comprehensive understanding of the portal's role in shaping the landscape of digital governance in Ukraine [7–9]. Furthermore, this paper seeks to evaluate the extent to which the Diia. Open Data portal has contributed to fostering civic participation and collaboration between the government and the public. Through case studies, analyses, and comparisons with international best practices, we aim to draw insights that can inform the ongoing development of the Ukrainian digital ecosystem [10–12] and contribute to the global discourse on the role of Open Data in shaping responsive and accountable governance structures [13]. As we embark on this exploration, it is imperative to recognize the significance of the Diia. Open Data portal [14] as a testament to Ukraine's commitment to harnessing the power of information for the benefit of its citizens. By examining the portal's impact, challenges faced, and lessons learned, we endeavor to contribute to the growing body of knowledge surrounding Open Data and its role in the evolving landscape of digital governance [15, 16].

2 Case Study of the Ukrainian Diia. Open Data Portal

The Open Data Portal is a Ukrainian government website designed to store public information in open data and provide access to a wide range of people according to the principles set out in the International Open Data Charter, which Ukraine joined in October 2016. The portal was created under the Law of Ukraine "On

Access to Public Information" [17] and Resolution of the Cabinet of Ministers of Ukraine No. 835 "On Approval of the Regulation on Data Sets to be Disclosed in the Form of Open Data" [17] dated October 21, 2015. The portal was developed by the Ukrainian technology NGO SocialBoost with the support of Microsoft Ukraine and the International Renaissance Foundation. The State Agency maintains the portal for the E-Governance of Ukraine [18, 19]. Ukraine's State Enterprise State Center of Information Resources administers the data.gov.ua portal. The public NGO SocialBoost initially developed the Unified State Web Portal of Open Data with the support of international organizations Microsoft Ukraine and International Foundation Renaissance.

The main tasks in creating the Unified State Web Portal and Open Data were:

- publishing and regular updating of open data on the portal by the information manager [20, 21];
- ensuring timely publication by the authorities of information subject to disclosure [22, 23], as well as any other data that meets the definition of public information in the form of open data;
- ensuring that all users of the information space have standard rules for publishing information materials in the form of open data [24–26];
- ensuring timely posting of complete and accurate information [27, 28];
- ensuring effective two-way communications and feedback channels [29, 30].

The first version of the portal was released in 2016. It had many shortcomings, so it attracted many negative comments from users and managers. In 2018, the portal was modernized by the Opendatabot team within the framework of the Transparency and Accountability in Public Administration and Services (TAPAS) project in cooperation with the Eastern Europe Foundation and the State Agency for E-Governance of Ukraine [31, 32]. The updated portal runs on the CKAN platform, unlike the previous version, which used a modified version of CKAN. This allows both managers to fully use the portal API to add datasets and users to download datasets from the portal. The portal now has the following new features compared to the previous version: premoderation; harvesting function, which allows for the automatic collection of data from other portals of cities or regions of Ukraine using the API, if these portals also support this function; publication of data under the terms of the Creative Commons license; ability to view data sets of certain types directly on the portal; forum; the ability to track the implementation of the Resolution of the Cabinet of Ministers of Ukraine No. 835 dated 21.10.2015 [17].

According to "Art. 101 of the Law of Ukraine," the central executive body that implements state policy in the e-government field is vested with creating and ensuring the functioning of a single state open data web portal. According to the Resolution of the Cabinet of Ministers of Ukraine No. 492, "On Approval of the Regulation on the State Agency for E-Governance of Ukraine," [17] dated October 1, 2014, the State Agency for E-Governance of Ukraine is such a body. The procedure for maintaining the Unified State Open Data Web Portal is regulated by the Resolution of the Cabinet of Ministers of Ukraine No. 867, "Some Issues of Public Information Disclosure in the Form of Open Data," [17] dated November 30, 2016.

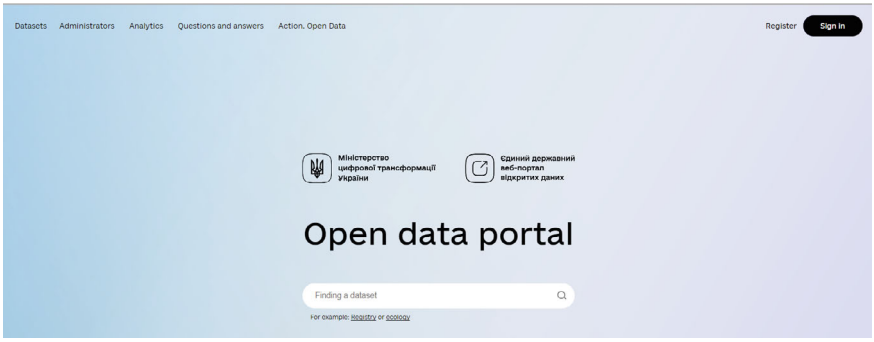


Fig. 1 Home page of the Open Data Portal

The webpage of this resource has a rather laconic and modest appearance, see Fig. 1.

Figure 2 shows a possible hierarchical structure of the service if we consider its possibilities and content. The portal consists of the following main sections:

- "**Datasets**"—information summarized by certain parameters (30,450 datasets in total);
- "**Managers**"—provides information about information managers: Central and local authorities;
- "**Analytics**"—contains the leading statistical indicators regarding downloaded data, views, etc.;
- "**Questions and Answers**"—the user can get an answer to a question relevant to this resource and of interest to users;
- "**Diia. Open Data**"—a link to the government portal Diia.

In general, we can draw an analogy between the hierarchy of the Open Data Portal and the hierarchy of a computer disk (Fig. 3). In this interpretation, the *Open Data Portal* is a personal computer disk containing all files and folders. *Data sets* are folders created by the user for different types of documents. *Resources* are files placed in specific folders with which the user can access and work.

Now, let us describe the structure and information on the portal in more detail. It should be noted that from the home page, there are direct links to the website of the Ministry of Digital Transformation of Ukraine and the Open Data Competence Center Diia. Open Data [33]. A user-friendly search bar also allows users to find datasets of interest using keywords. To simplify finding the information users need, the developers also put the most popular objects of interest on the main page, classifying them into specific categories (Fig. 4).

At first glance, one can already identify the first drawback: information can only be viewed in Ukrainian. Given that this is a government resource [34, 35] intended to provide information services mainly to Ukrainian citizens, the question arises

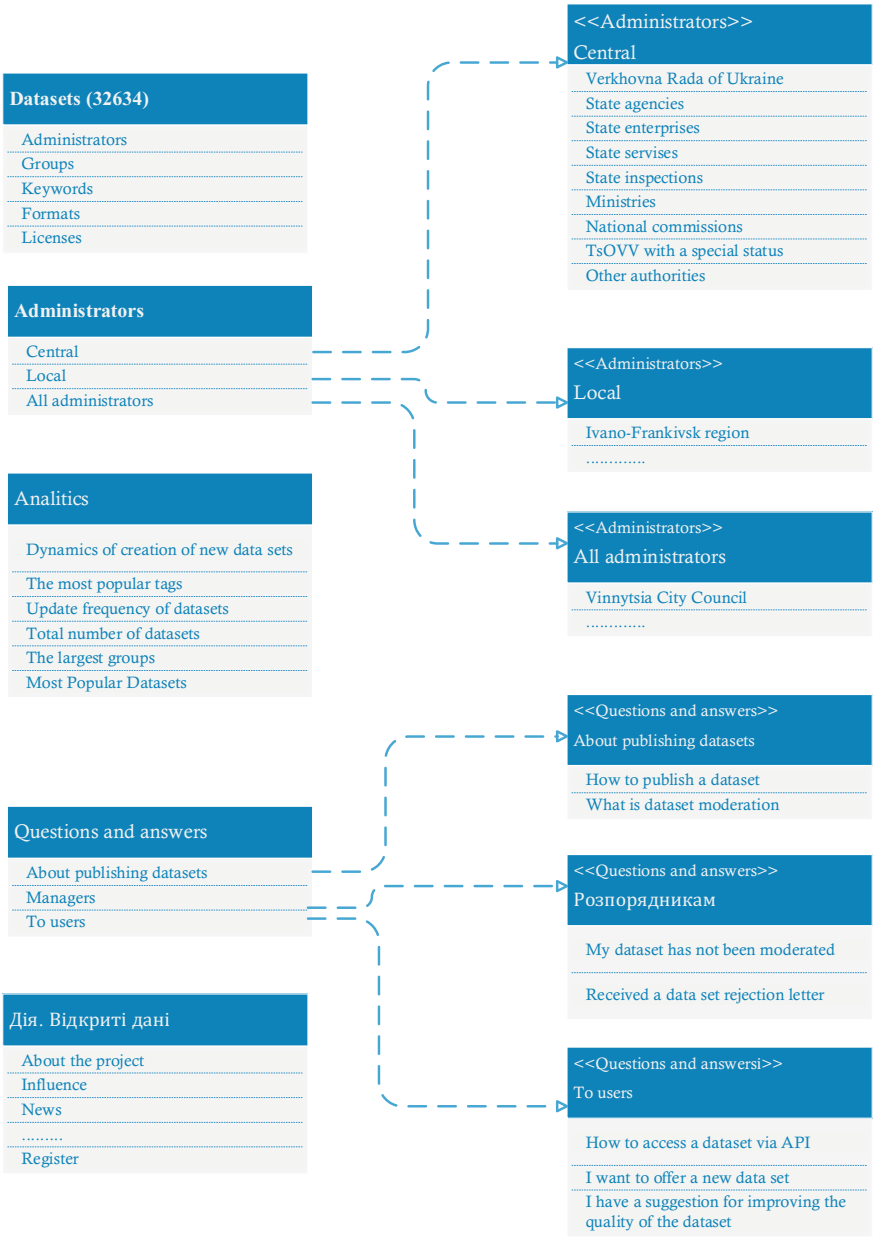


Fig. 2 Structure of the Open Data Portal resource (Site Map)

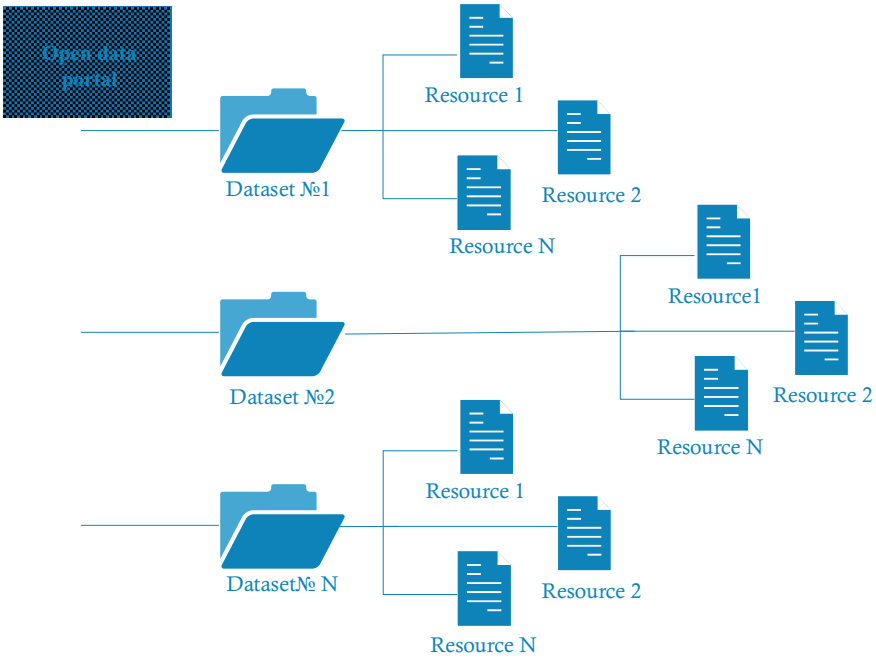


Fig. 3 Scheme of organization of the structure of the open data portal

Fig. 4 Datasets by industry

whether it is advisable to translate into other languages at all. The developers may take care of this in future versions.

Datasets tab. This section contains 27,063 different datasets in total. They are mainly intended to inform legal entities and individuals. The only problem here may be the untimely publication that has lost relevance. The tab can be logically divided into 2 parts: a list of documents already uploaded by managers (it is possible to sort by certain criteria) and a panel with categories (Fig. 5).

The developers have provided the following categories by which the information on the website is divided:

Administrative bodies include documents posted by or related to a particular city, regional council, or territorial community. They are primarily structured around territorial communities' centers.

If the user selects the Manager user need, the user will be taken to the page with its datasets (Fig. 6). Information about this particular manager's number of data sets is immediately provided. There are also categories by which this data is divided: Groups, Keywords, Formats, and Licenses.

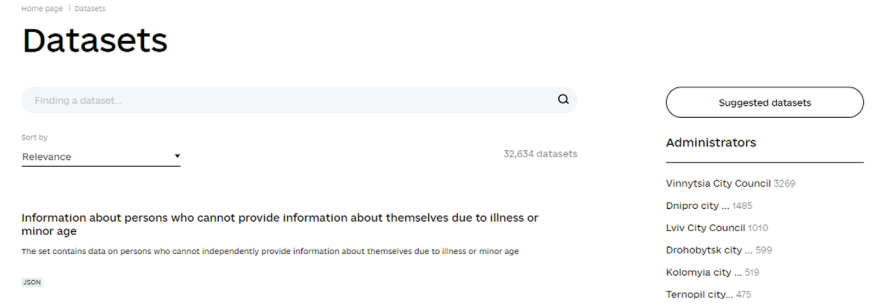


Fig. 5 Structure of the "Datasets" tab

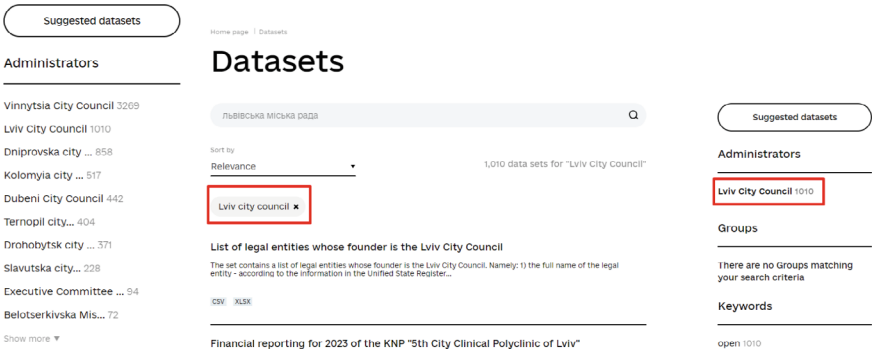


Fig. 6 Datasets of the category "Managers"

Groups. The information is presented in several categories, depending on the area of interest (Figs. 7 and 8).

As in the previous case, the user can get data on the number of sets in a given category.

Keywords. Users can find data by keywords. The 50 words selected were of the most significant interest to users.

Formats. The user can see the most popular formats in which data is published on this service. There are as many as 50 of them on the list. If the user carefully analyzes the list, they will notice that some are repeated several times so that they can be optimized (Fig. 9).

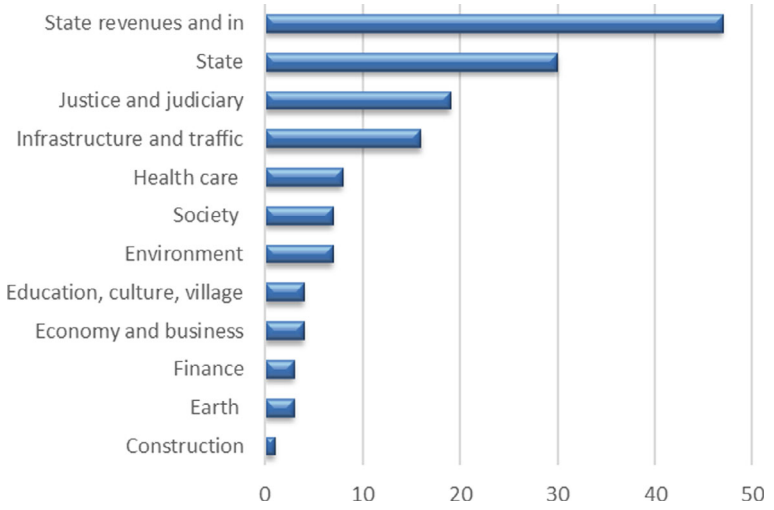


Fig. 7 The diagram shows the number of records in the "Groups" category

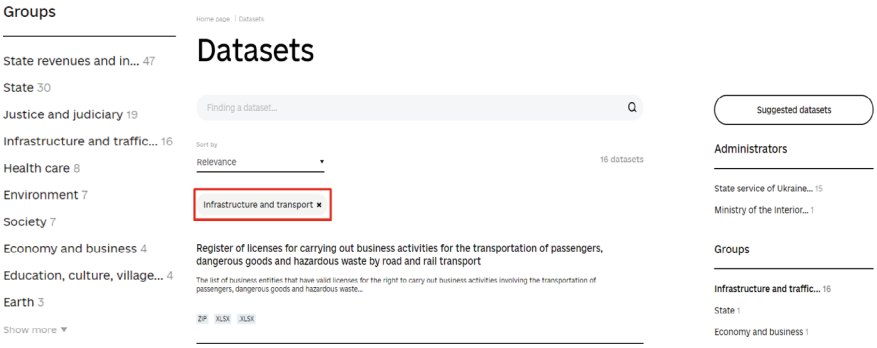


Fig. 8 Datasets of the category "Groups"

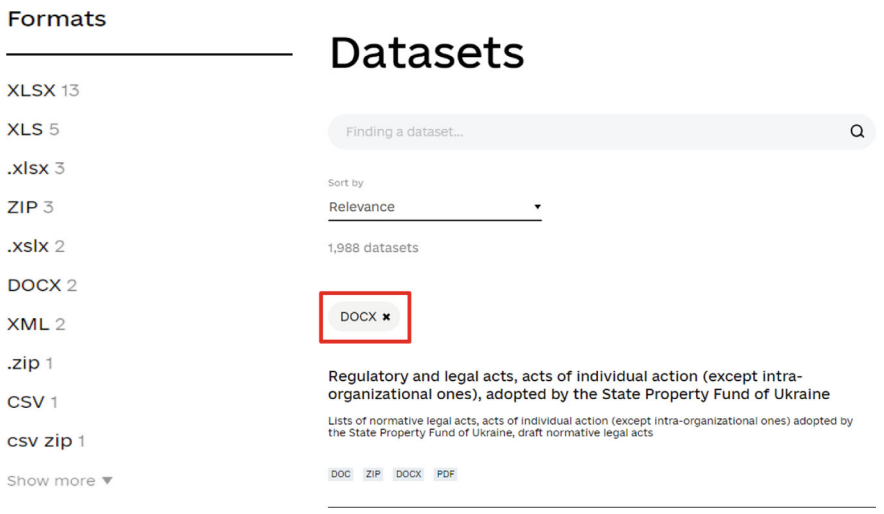


Fig. 9 Datasets in the "Formats" category

Licenses. Users can see the list of signed licenses in 8 categories.

For each item described above, the user can also find information on how many documents in a particular area are publicly available and can be read without problems (Fig. 10).

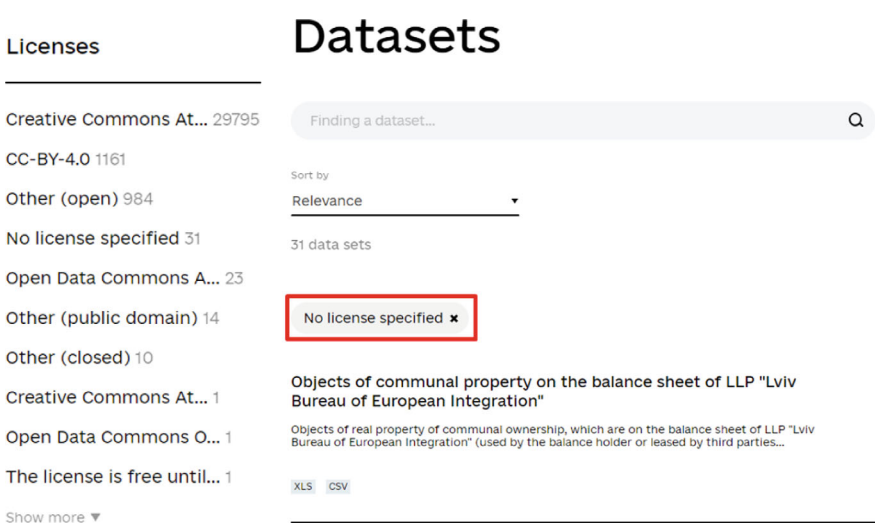


Fig. 10 Datasets of the category "Licenses"

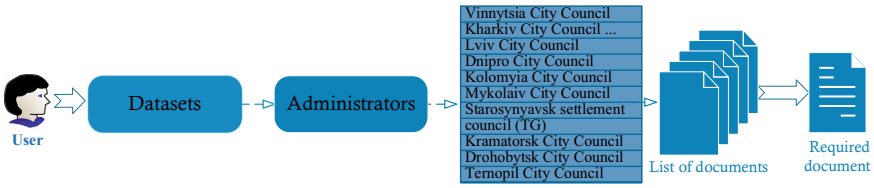


Fig. 11 Scheme of access to a specific document

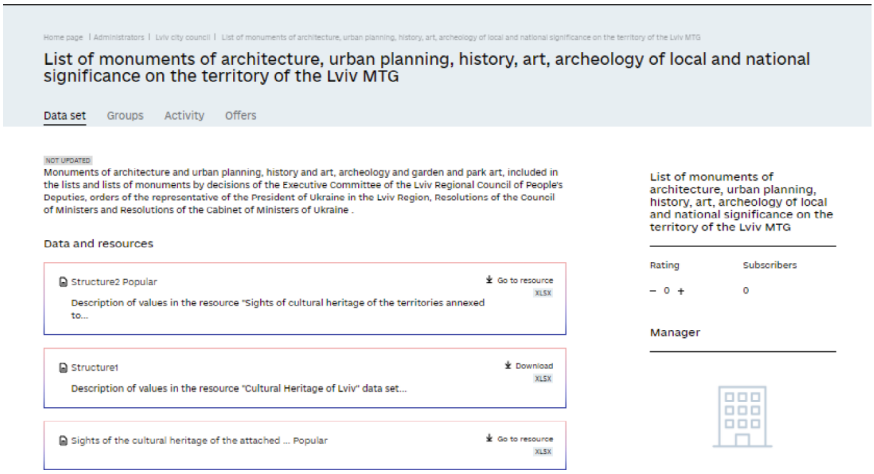
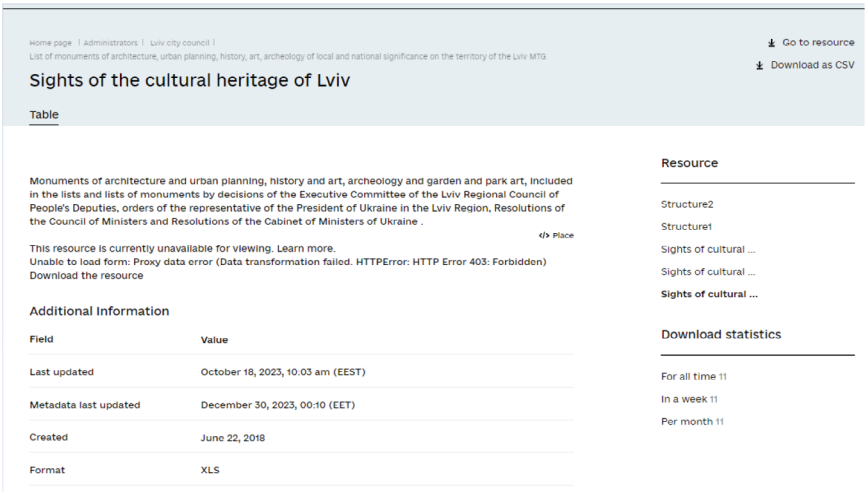


Fig. 12 Information about the document

If the user opens an arbitrary data set, the user can get the following information about the manager according to the scheme shown in Fig. 11, and then the user can get information about this data set (Fig. 12):

The user can view a list of fields with additional information about this dataset: responsible person, last update, frequency of updates, etc. Statistics on the views of this dataset are also important. By analyzing them, the user can conclude their interest in this dataset. This item is also important for identifying the areas of interest of resource users. So, we have smoothly reached the set of tributes itself. This file is classified into a certain section, uploaded by the Administrator, and contains arbitrary information.

It should be noted that there are no clear recommendations or standards for what format or form the dataset should be in. Acceptable formats include.doc,.docx,.pdf, and others. Since the resource is intended for posting regulatory documents, each has its nomenclature and requirements. If the user selects an arbitrary document, the user cannot view it in a browser window or on a page. They are downloaded directly to the PC. In our case, it is an Excel spreadsheet with information about the architectural monuments of Lviv (Fig. 13).



monument_name	monument_location	monument_dates	monument_type	protection_decision	protection_number
The building of the City disinfection facility	00th anniversary of Lviv, square, 2; C	XIX ст.	Architectural monument	Order of the Representative of the President of Ukraine No. 374 of April 15, 1994	4002-Лв
Villa	Azovska str., 2	1930-s	Architectural monument	Order of the Representative of the President of Ukraine No. 374 of April 15, 1994	4003-Лв
Villa	Azovska str, 3	1930-s	Architectural monument	Order of the Representative of the President of Ukraine No. 374 of April 15, 1994	4004-Лв
Villa	Azovska str, 4	1930-s	Architectural monument	Order of the Representative of the President of Ukraine No. 374 of April 15, 1994	4005-Лв
Villa	Azovska str, 6	1930-s	Architectural monument	Order of the Representative of the President of Ukraine No. 374 of April 15, 1994	4006-Лв
Villa	Azovska str, 7	1930-s	Architectural monument	Order of the Representative of the President of Ukraine No. 374 of April 15, 1994	4007-Лв

Fig. 13 The information about the architectural monuments of Lviv

2.1 Managers Tab

This section contains information on the list of government agencies that have published their datasets.

In the "Managers" section of the website, managers are divided into categories:

- **Central** (the Verkhovna Rada of Ukraine, Ministries, State Services, State Agencies, State Inspectorates, CEBs with special status, Other authorities, National Commissions, and State-owned enterprises);
- **Local** (administrators of all regions of Ukraine, as well as the Autonomous Republic of Crimea, Kyiv, and Sevastopol);
- **All managers**. (Fig. 14) collects all managers sorted according to the number of downloaded datasets.

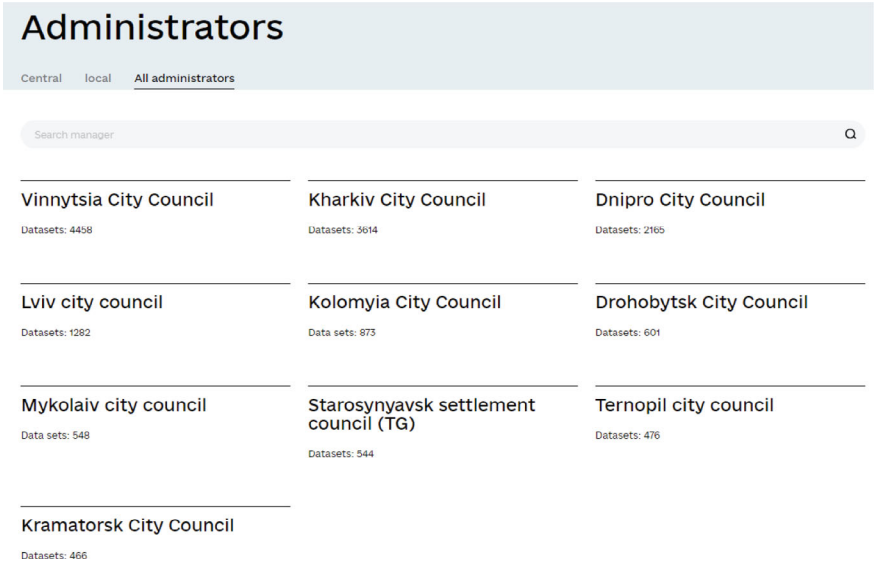


Fig. 14 The "Managers" section

2.2 Analytics Tab

In this analytical section (Fig. 15), users can see analytical information about the intensity of the resource, the most popular resources, the frequency of data updates, and other categories (Figs. 16, 17 and 18). The data is displayed in the form of graphs and charts. This page is highly informative, empowering users to assess the service, the most popular datasets, documents provided by various criteria, visit statistics, etc. This information is crucial to understand the widespread and necessity of the portal from both the users' and the government's point of view.

In this case, the graph shows that no new datasets were created from 01.2022 to 08.2022. This is due to the outbreak of hostilities on Ukraine's territory, and the service was suspended to prevent unauthorized information leakage. This situation also changed the dynamics of other statistical indicators, such as the Total number of datasets and API statistics (see Figs. 19 and 20).

Fig. 15 Analytics sections

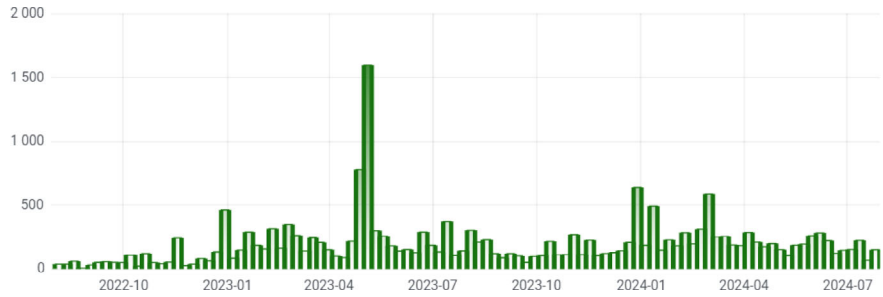


Fig. 16 Statistics on new datasets creation

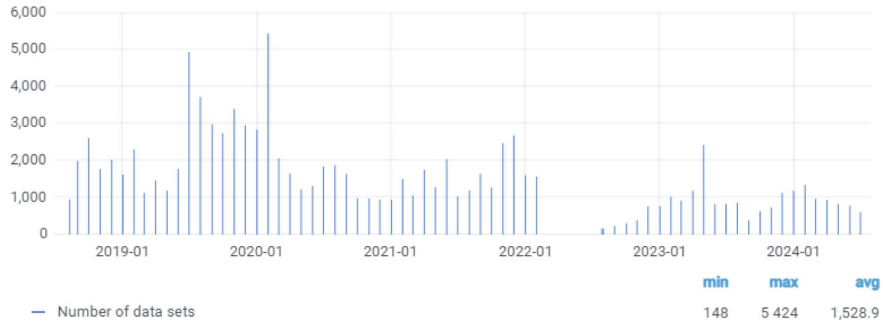


Fig. 17 Statistics on publication of new sets

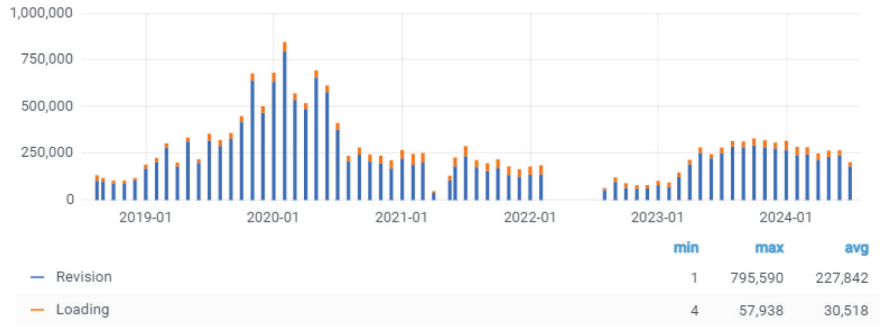


Fig. 18 View and download datasets

Users can also use information about the most popular datasets (Fig. 21).

Users can find answers to questions they are interested in regarding open data. Again, the resource administrators collected a bank of questions and sorted them into certain categories. Therefore, there are two ways for the user:

Fig. 19 Statistics of the total number of datasets

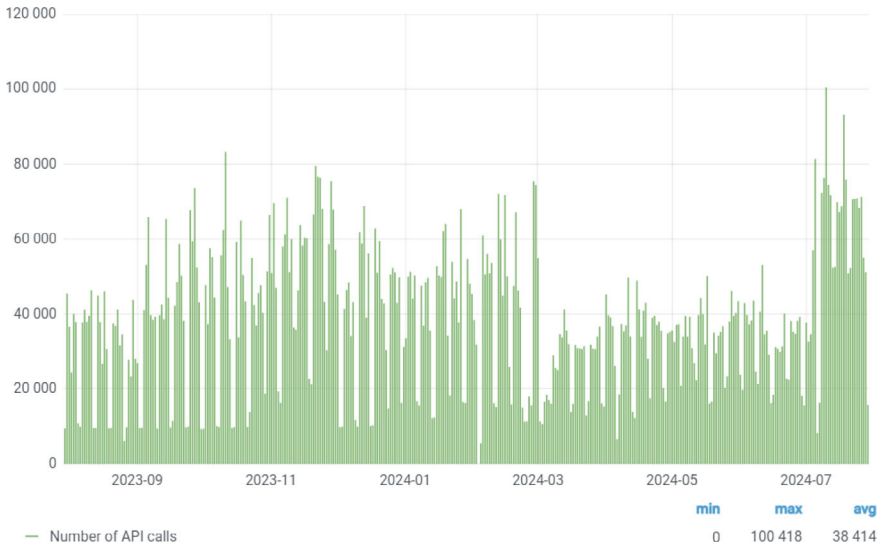


Fig. 20 Data from the "Analytics" section

- or search for a conditional topic of user question among the already processed options (Fig. 22);
- or fill in a specially designed field; the answer will come shortly (Fig. 23).

2.3 Action. Open Data

Diia. Open Data is an online portal for working and learning with open data. It will become the main source of information and communication in the field of open data [36–38] and will help improve Ukraine's position in international anti-corruption rankings. This was announced during the Ukraine 30 All-Ukrainian Forum (Fig. 24).

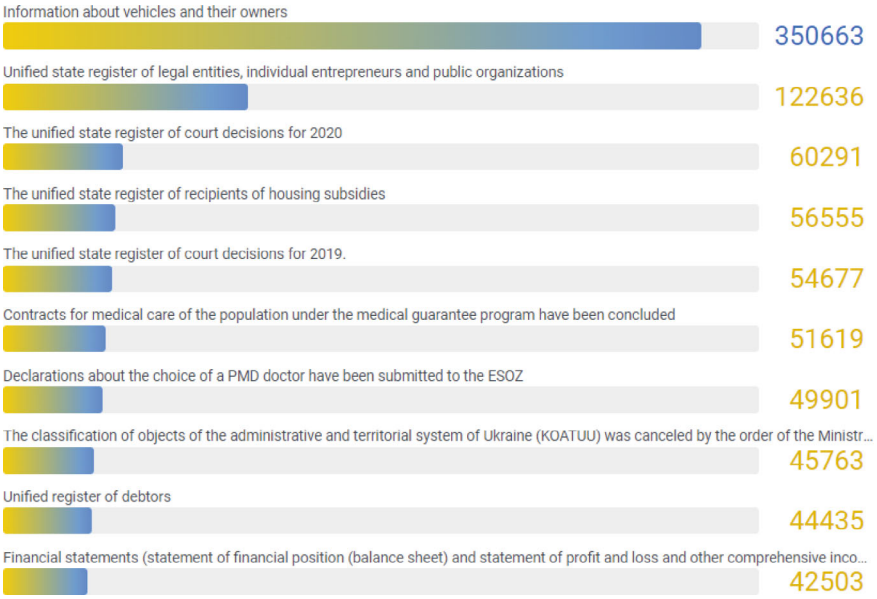


Fig. 21 The most popular datasets

Fig. 22 The most popular questions

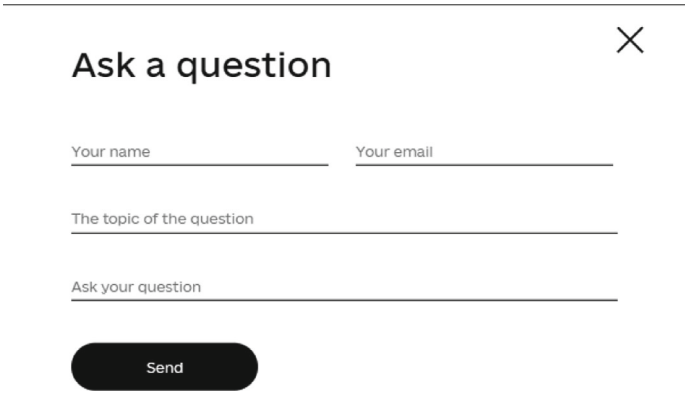
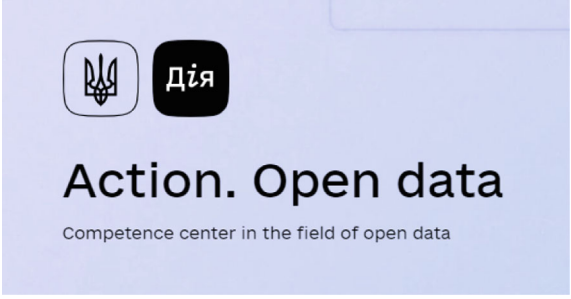


Fig. 23 Form for displaying a user question

Fig. 24 Diia. Open Data



The portal "Diia. Open Data portal" offers a number of opportunities for both government agencies that manage data and IT professionals, business representatives, NGOs, the startup community, and ordinary users:

- ***Training programs for four categories of users***. Those interested will be able to determine their level of knowledge and take advantage of the proposed development plan, which includes, among other things, online and offline training to improve their literacy level.
- ***Services based on open data to solve everyday problems***. Whether it's checking the developer when buying a home, preparing for a dispute in court, finding out the level of water pollution, or finding cheaper drug analogs, open data can help with all of these. Areas and user needs structure all services.

  Research assessing and analyzing open data's impact on solving social problems.

  Communication between the community and collection of proposals from the public on forming a national open data policy. News and the most complete information on open data.

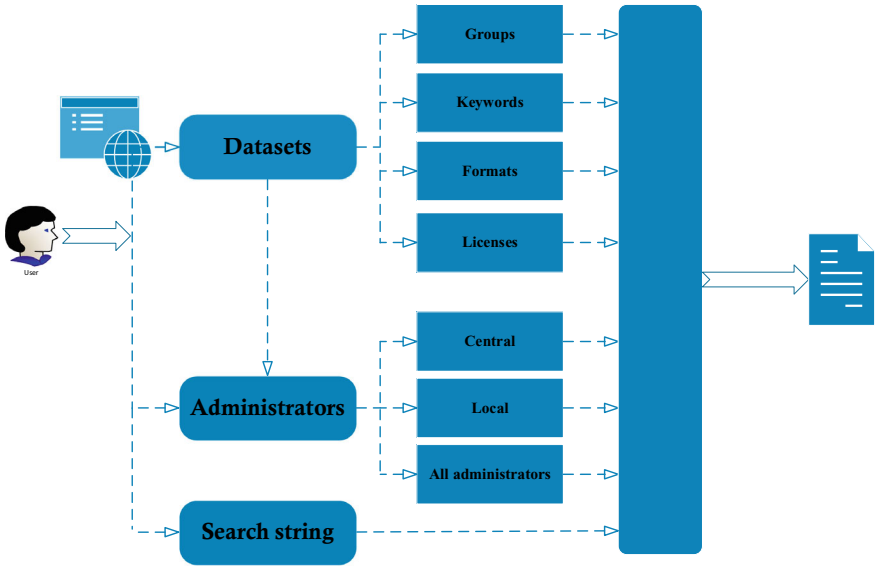


Fig. 25 Conditional scheme for finding the desired data set

This page can be treated as a separate service with many different functions, so describing all its features here is inappropriate.

Search for information on the Open Data Portal

There are several ways to get the information users need (Fig. 25):

1. Enter keywords in the search bar. The system will then display a list of datasets that fit the keywords, and users need to select the one that best meets their information needs.
2. through the Data sets item;
3. through the item Managers.

Each of these methods has its peculiarities. For example, if a user needs to become more familiar with the structure of a resource but knows what he or she needs to find, it is advisable to use the first method. Enter one or more words for the user information request.

The next step is to select the desired file from the proposed ones, provided that one of the administrators has uploaded a file in the name of which there are words that the user entered in the query (for example, the word “mosaic” was used). It should be noted that in this case, the search for matches in the document’s name with the query is performed. After analyzing the work with keywords, we managed to identify many shortcomings:

1. Full-text search is not provided. This is logical because, among such a large number of documents, full-text search would take quite a long time, and the service is already quite slow.
2. Only displays results if an absolute match exists between the phrase in the search query and one or more words in the document title. Of course, this is not very convenient because if the user makes a mistake in one letter, he or she will not get the document he or she needs.

These features are illustrated by the following example (Fig. 26).

In this case, the word is used in different cases and is therefore interpreted by the system as different concepts, which leads to negative consequences for the user.

There are other ways to get the information users need. In this case, the user must have at least some information about the Administrator or the section to look for it. One of the previous paragraphs describes the sequence of actions in this case.

2.4 Registration and Publication of Data on the Portal

According to Resolution of the Cabinet of Ministers of Ukraine No. 867 "Certain Issues of Public Information Disclosure in the Form of Open Data" [17] dated November 30, 2016, the portal owner shall register the information manager on the portal based on a relevant application for registration of the information manager.

The application for registration of an information administrator on the portal is generated automatically when creating a personal electronic cabinet, after which it is printed and certified by the signature of the head and the seal of the information administrator or by the electronic digital signature of the head and the electronic digital seal of the information administrator and sent to the portal owner—the State Agency for Electronic Governance of Ukraine.

Downloading the application form from data.gov.ua during registration is recommended. To do this, click the "Register" option in the upper right corner of the main page (Fig. 27).

As a result of the above steps, the user will get access to the electronic application form. The user must fill in the provided fields in two categories and submit them for verification. Below, the user can see an example of what such a document form (application) looks like.

When entering information on the website during registration, it should also be noted that the e-mail and contact phone number should be provided by someone other than the customer directly but rather by the contact person responsible for the publication of the datasets.

The portal owner shall, based on the executed application for registration of the information manager, within three business days from the date of receipt of such application, decide on registration and granting the relevant access rights to the information manager on the portal. Suppose the data contained in the application for registration of the information manager is incomplete and contrary to the law. In that

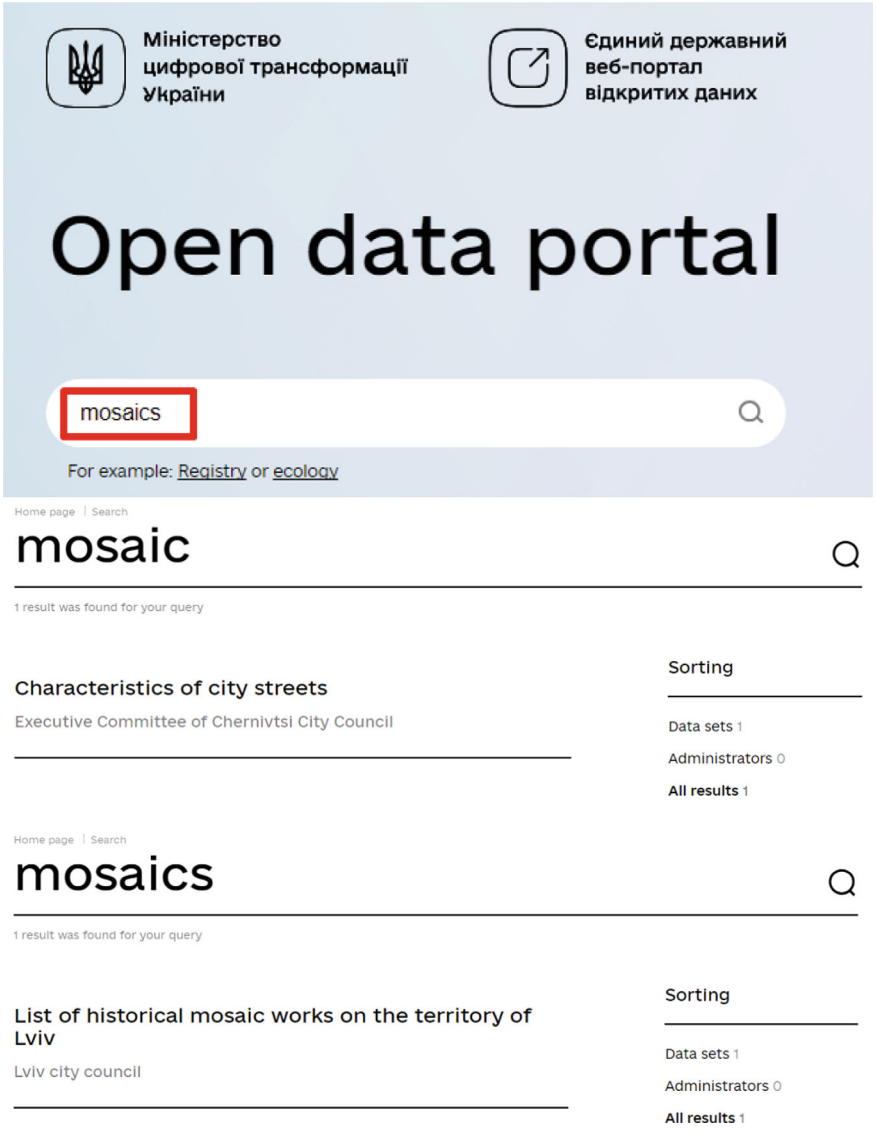


Fig. 26 An example of using a search engine

case, the portal owner shall, within three business days from the date of receipt of such application, inform the person responsible for the information manager of the need to eliminate the identified discrepancy and resubmit the application for registration of the information manager after the user receives the rights of an information manager (Fig. 28).

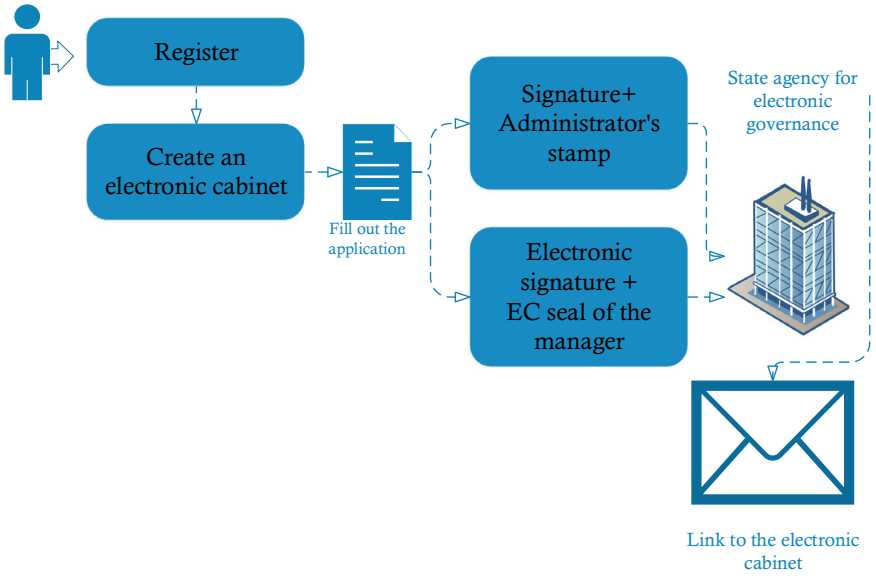


Fig. 27 The algorithm of registration in the data.gov.ua

Next, to upload the dataset, the user must follow the link to the user's account, select the "Add dataset" tab, fill in all the necessary fields, and click the "Create" button. The dataset passport will be created if all fields are filled in correctly. If an error occurs, the user will need to go back to the stage of filling in the fields and check the correctness of all the entered data. In addition, obtaining the right to manage information is accompanied by sending the Instructions for the Information Manager of the Unified State Open Data Portal [39, 40] to the user's e-mail address (specified during registration). So, as a user can see, if the user follows all the above steps, the user will quickly obtain the rights of an information manager and be able to publish the user's annual plans on the Unified State Open Data Portal.

3 Results

According to statistics from the Similar Web service [41], Diia online government services are widely used by citizens in Ukraine and abroad. From May 2024 to July 2024, the total traffic to Diia's online government services amounted to 9.758 M worldwide. The statistics of visits to this service increased by 18.75% over the past month (see Fig. 29). 45.84% of users access the service using a desktop computer, but 54.16% of users use mobile devices to access Diia online government services.

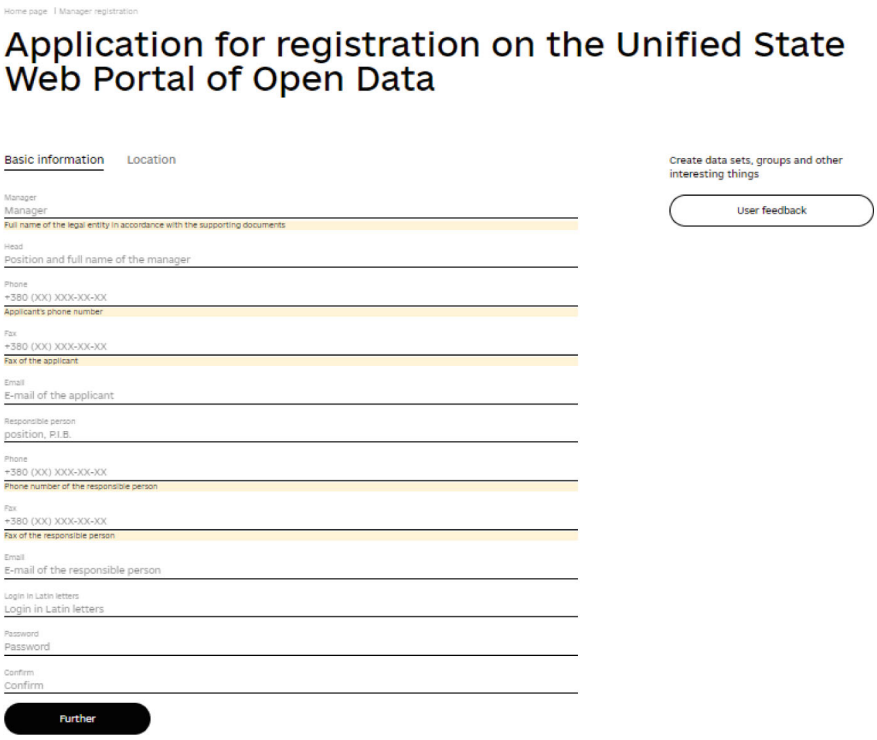


Fig. 28 Application form for registration in the URTI

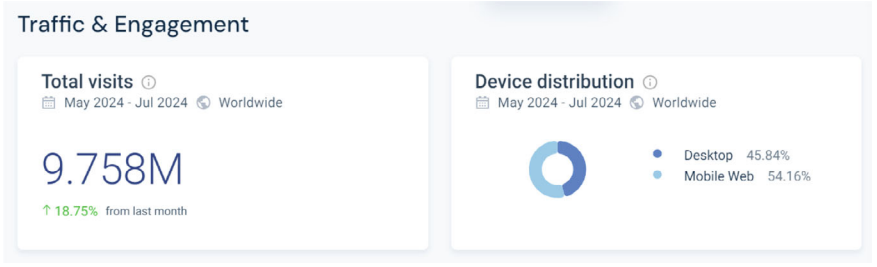


Fig. 29 Statistics of traffic and engagement, total visits, May 2024–Jul 2024, worldwide

According to the statistics of top countries (Fig. 30), May 2024–July 2024, 88.68% of all users used Diia's online government services in Ukraine, more than 2% from Poland and Germany, and less than 1% of users accessed the service from the United States and the United Kingdom.

Figure 31 shows statistics of referrals for Diia online government services: Referrals account for 5.19% of website traffic, indicating the top referring websites and industries.

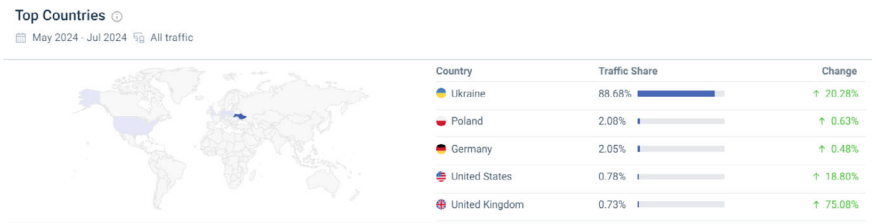


Fig. 30 Statistics of top countries, May 2024–Jul 2024, all traffic

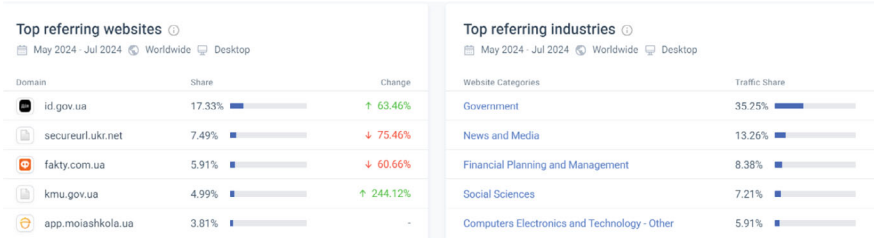


Fig. 31 Statistics of referrals, top referring websites, and top referring industries

Statistics of Visits over time of online government services Diia are presented in Fig. 32. According to these statistics, 9.758 M users used Diia's online government services worldwide between May 2024 and July 2024.

In conclusion, the analysis of Diia's online government services from May 2024 to July 2024 demonstrates significant and growing engagement, both within Ukraine and internationally. With a total of 9.758 million visits during this period, the service has seen an 18.75% increase in traffic over the past month. The majority of users access the platform via mobile devices (54.16%), highlighting the importance of

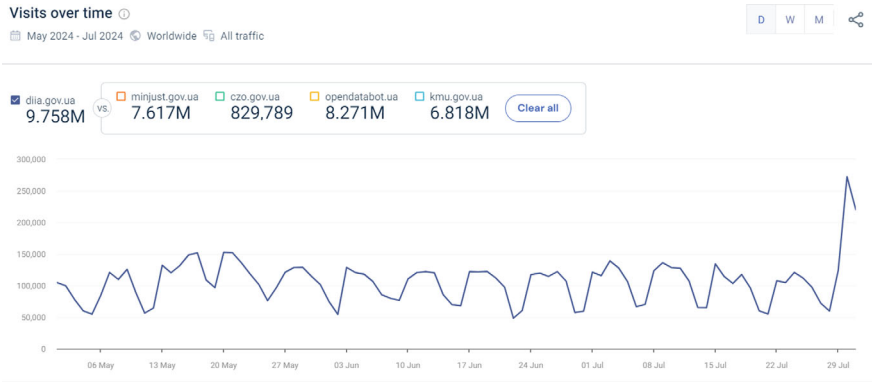


Fig. 32 Statistics of visits over time, May 2024–Jul 2024, worldwide, all traffic

mobile accessibility for public services. Additionally, while the service remains predominantly used by residents of Ukraine (88.68%), there is noticeable engagement from users in Poland, Germany, the United States, and the United Kingdom. Referral traffic, contributing 5.19% of the total visits, underscores the role of external websites in driving users to Diia's platform. Overall, these statistics reflect the broad reach and growing importance of Diia's online government services in providing accessible and efficient services to citizens both in Ukraine and abroad.

4 Conclusion

Assuming the above information regarding the structure, content, and functioning of the Open Data Portal, we can say that this resource represents a significant breakthrough in public disclosure. However, the resource's analysis would be incomplete without emphasizing its strengths and weaknesses. Disadvantages of the service:

- News updates are not systematic;
- The website is only available in Ukrainian;
- When searching for data through a search string, there is a problem with parsing;
- The server is quite slow;
- There is no forum for discussion.

Advantages of the service:

- free access;
- fast functionality;
- the site is easy to use;
- availability of feedback;
- the ability to download and print the necessary data from the website;
- all data is open and available to any citizen online;
- data is regularly updated, so users can be sure that the information is up-to-date;
- common rules for all users;
- different formats are used when publishing datasets.

Communities benefit from the service, which provides information about municipalities. Users can also check whether they are registered to receive reliable and up-to-date information on open data "firsthand." All documents must be sorted by belonging to a particular city or regional council, which is convenient for the user.

Acknowledgments This research is supported by the National Scholarship Programme of the Slovak Republic.

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Methods and Tools for Implementing Educational Web Projects in Social Media on the Internet

Olha Trach

Abstract The article presents the definition of types of educational projects, namely: web projects that provide educational services online, web projects that advertise educational projects. The main characteristics and types of educational web projects are described. Platforms in social media for creating educational web projects are identified. The requirements for creating an official page for promoting an educational web project in social networks are determined. The algorithms for creating information content for the promotion of an educational web project in social media and choosing a platform for creating an educational web project are presented. The results of the activity of an educational web project advertising educational services are presented on the example of a department of a higher education institution, namely the Department of Social Communications and Information Activities of Lviv Polytechnic National University.

Keywords Social networks · Online learning · Virtual communities · Business strategy

1 Introduction

Today, due to the continuous development of online social environments, digitalisation of the population, the COVID pandemic, military operations and other factors, all spheres of life are adapting to online activities. Education is no exception. Self-education and self-development are growing in fashion and relevance among the younger generation. They get information not only from printed materials, but also from the Internet. Online learning is gaining relevance because the student is not tied to a specific location, time and in comfortable conditions. Also, in a short period of time, you can acquire the basics of skills and knowledge in a particular field and educational level. For example, during the covid pandemic, physical fitness courses

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and marathons became very popular, offering participants a list of exercise exercises, a menu with proper nutrition, and support from a qualified trainer and nutritionist. Online foreign language courses are also popular.

In addition, the representation of stationary educational institutions in social media is a significant part of educational web projects. Presenting a product or service on social media is a quick and relevant way to make yourself known to the general public. The creation of official pages of educational institutions on social media is gaining popularity. This is especially relevant for attracting applicants. The use of social media for branding educational institutions and their departments has not been fully explored. The use of official pages on social media for career guidance and advertising activities of educational institutions has not been studied either.

Based on the above, it is relevant to study the creation of educational web projects, both for online learning and for the branding of educational institutions in social media on the Internet.

2 Literature Review

Researchers have also studied students views on online learning during the pandemic, as the coronavirus outbreak has challenged the education system around the world and forced teachers and students to instantly switch to online learning and adapt to the needs of the times [1–7]. In fact, this gave a powerful impetus to the faster transition of education and self-improvement in the online space.

In the article [8], the authors conducted a comprehensive bibliometric analysis to provide a holistic view of online learning research in higher education worldwide during COVID-19. The research showed that scholars from more than 100 countries have investigated a wide range of forms of online learning, such as the use of different technologies and strategies, redesigned curricula, student perceptions, and the psychological impact of online learning caused by the pandemic.

The authors in [9, 10] analyze the experience of distance learning in academic education, the impact of online learning on mental health, and future decisions about enrolment in courses and obtaining higher education online.

Also, researchers argue that the transition to online learning has affected social interaction [11], that students' communication in discussion forums in massive open online courses significantly affects their epistemic emotions, motivates them, and helps them interact better in society, but there is also a change in team methods of supporting and maintaining social interaction in the online environment [12].

The authors also pay considerable attention to the use and usefulness of social media and mobile devices for transferring resources and interacting with students and teachers in educational institutions [13–18].

Scholars pay considerable attention to the positioning of higher education institutions in social media. Researchers study the formation of the information image of higher education institutions in social networks, determine the stages of building the

image of an educational institution in social networks [19], determine the effectiveness of information activities of educational institutions on the Internet [20], study the provision of management activities of administrative and information units of educational institutions and information activities on the Internet [11].

3 Types of Educational Web Projects

In recent years, many factors (technology development, digitalisation of the population, the covid pandemic, wars, etc.) have influenced the transition of most areas of life to the online space of social media on the Internet. Advertising and selling goods and services through social media and other online social services has become much faster and more convenient. And the sale and advertising of educational services is no exception. On the contrary, online educational courses, including foreign language learning, sports courses, programming courses, etc., have become popular. In addition, educational institutions have started to create official pages on social media to represent themselves. Therefore, it is important today to create high-quality educational web projects and present educational products on the Internet.

The statistics of search queries in Google Trends shows that Internet users often search for online courses (Fig. 1). Also, the query statistics show that searching for online foreign language courses is a popular query (Fig. 2).

Educational web projects [21] are projects created to promote educational services and create online educational services.

Educational web projects can be divided into two types (Fig. 3):

- web projects that provide online educational services
- web projects that advertise educational projects.

Web projects that provide online educational services are projects that provide educational services exclusively in the online space [22]. This type of educational services has gained popularity primarily for the possibility of learning without reference to a specific place or time. The participant of such an educational process manages his or her own learning plan and schedule, which contributes to self-improvement and self-education.

The most popular web projects that provide online educational services are:

- Online educational institutions that provide distance learning for secondary and higher basic education. The term of study is in accordance with the license conditions issued by the Ministry of Education or the Agency for Quality Assurance in Education. The license is issued exclusively by the state authorities and the online educational institution operates according to the rules and requirements of the Ministry of Education and Science. For example, online schools that are an accredited educational institution but operate exclusively online without being tied to a specific location.

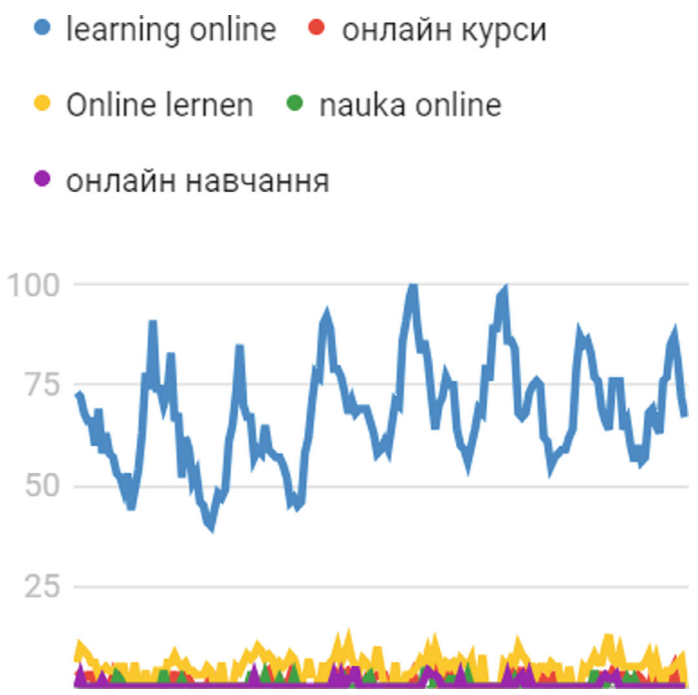

Fig. 1 Google Trends statistics

- Online courses are about gaining comprehensive skills and theoretical knowledge in a comfortable environment. The duration of online courses is usually 1 to 3 months. These are usually interactive platforms for online learning in various fields and levels. It is also an opportunity to get quick and accurate knowledge in the area you need. Participants of such courses seek new knowledge, advanced training or self-improvement without spending time or money on travelling to a service provider.
- Marathons and intensives are about acquiring the first knowledge and skills in a particular field in a short period of time. The duration of marathons and intensives is up to 1 month and includes 10–15 training lessons. For example, marathons and intensives are popular sports activities for getting fit.
- A workshop is the shortest format of online learning for acquiring and practicing just one skill. The duration of such training is 1–3 days. The peculiarity of workshops is the high interaction of participants and the intensity of the learning process.
- Others include combining different types of learning in one educational web project.

Web projects that advertise educational projects are projects that promote the online activities of educational institutions in social media.

The most popular web projects advertising online educational services are:

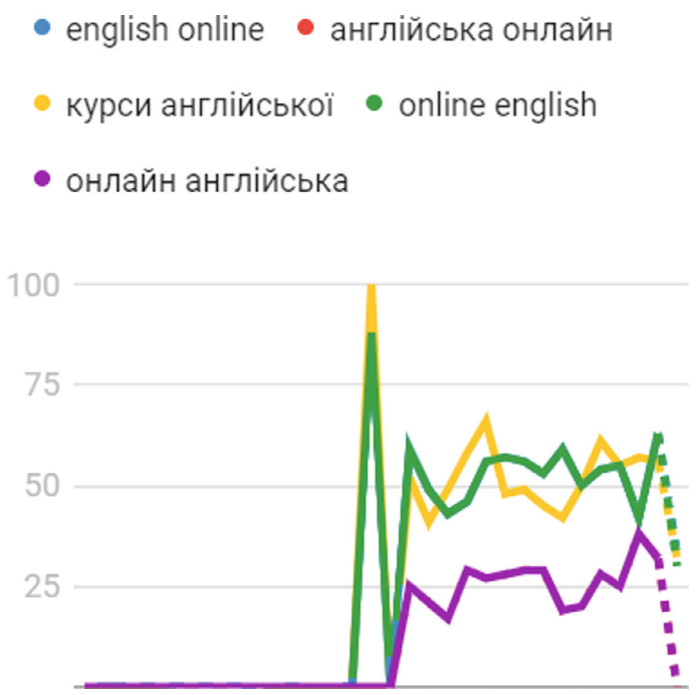

Fig. 2 Google Trends statistics

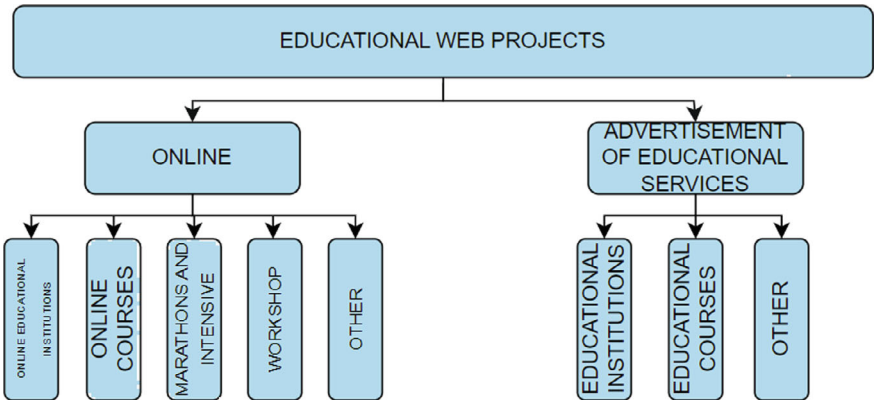

Fig. 3 Types of educational web projects

- Advertising of educational institutions is the advertising activity of educational institutions in social media on the Internet. An educational institution (school, college, university, etc.) creates an official page of the institution's representation on social media or other social media platforms. For educational institutions, this

is their online business card, information about their activities and platforms for advertising their services to attract new students.

- Advertising of educational courses is advertising of educational courses that operate exclusively offline. Often, it is possible to acquire new skills and knowledge only when you are stationary in the relevant space. But this also requires advertising activities, and the social media platforms of the Internet are perfect for this.
- Others include other educational services that require advertising and blended learning.

4 Social Media Platforms for the Implementation of Educational Web Projects

The implementation and promotion of educational web projects takes place on various platforms in social media. In particular, Fig. 4 shows the most popular platforms for implementing educational web projects, which were identified through the analysis of existing educational web projects.

Implementing educational web projects with the help of social media is one of the easiest ways to do it. Most often, advertising campaigns for educational institutions, courses and services are carried out by creating a virtual community within a social network. The most common social networks for creating educational web projects are the following: Facebook, Instagram, YouTube, TikTok, LinkedIn. Creating virtual communities based on social networks is the best option that will be a good option for many types of educational web projects. You can also create and develop virtual communities of educational web projects in several social networks simultaneously depending on the target audience.

Messengers are usually used for quick messaging. However, instant messengers can be used to develop group chats and chatbots, which are perfect for implementing

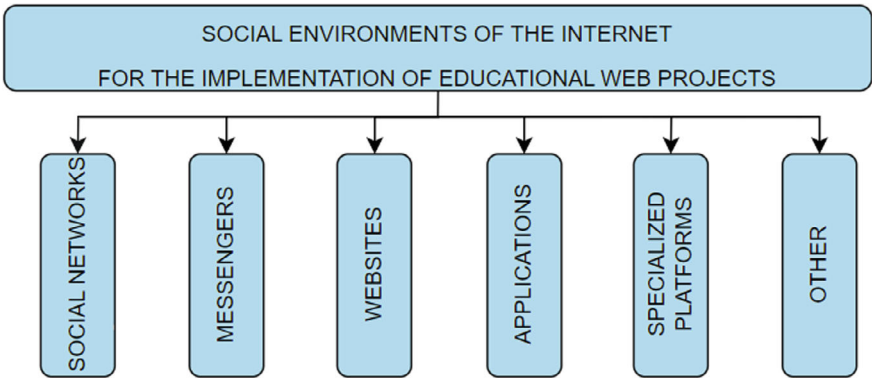

Fig. 4 SEI for creating educational web projects

educational web projects. Group chats allow you to communicate with the participants of a web project and provide quick feedback. You can develop an educational course based on the functionality of chatbots. Also, messengers have the appropriate functionality to create communities where you can carry out advertising activities of an educational web project.

Creating an educational web project based on a **website** is one of the best options for creating a virtual learning environment. A virtual learning environment is an information resource for learning, created on the basis of website development technology, that allows communication, file sharing, testing, assignment evaluation, polls, and more. Virtual environments are typically used by higher education institutions for distance learning, but also for private training courses. In addition to creating new websites to host educational web projects, there are also many websites where you can host your educational course, for example: Prometheus, EdEra, Coursera and others.

Creating **applications** for educational web projects is a great solution when creating a training course. The use of a mobile application is becoming more popular, as participants of an educational web project are more effectively involved in the learning process and have the opportunity to study without being tied to a specific location. Also, mobile applications provide an opportunity to develop a training plan and schedule, reminders and motivation, which makes it easier to master course materials.

The use of **specialized platforms** for creating online courses is one of the best platforms for implementing educational web projects. As a rule, such platforms include a wide range of functionality, such as web platforms, mobile applications, CRM systems, email and SMS campaigns, chatbots, etc. Such functionality allows you to create large educational courses and access for participants from anywhere in the world, communicate with them, exchange materials, etc.

Others include a combination of different platforms of social media for creating educational web projects. The combination depends not only on the chosen topic of creating educational web projects, but also on the technical and material resources allocated for the project.

5 Formal Model of an Educational Web Project

Let's describe the formal model of an educational web project using a tuple:

$$EduWP = OnlineEdu, AdverEdu \tag{1}$$

where *OnlineEdu*—web projects that provide educational services online, *AdverEdu*—web projects that advertise educational projects.

$$OnlineEdu = Platform, Content, Users, Team \tag{2}$$

where *Platform*—social media platforms on the Internet where the training course is posted and advertised, *Content*—information content of the online course (training materials), *Users*—course participant, *Team*—the team of executors of the educational web project.

$$Platform(OnlineEdu) = \{Platform_i(OnlineEdu)\}_{i=1...N^{Platform}} \tag{3}$$

where $Platform_i$—is the platform on which the educational project is created and where the advertising activity is carried out, $N^{Platform}$—is the number of platforms of the educational web project that provide online educational services.

$$Content(OnlineEdu) = \{Content_i(OnlineEdu)\}_{i=1..M^{Content}} \tag{4}$$

where $Content_i$—is the information content of the educational project course, $M^{Content}$—is the amount of content of the educational web project that provides online educational services.

$$User(OnlineEdu) = \{User_i(OnlineEdu)\}_{i=1..M^{User}} \tag{5}$$

where $User_i$—is the i-th participant of the educational project course, N^{User}—is the number of participants of the educational web project providing online educational services.

$$Team(OnlineEdu) = \{Team_i(OnlineEdu)\}_{i=1..M^{Team}} \tag{6}$$

where $Team_i$—is the i-th member of the educational web project team, N^{Team}—is the number of members of the educational web project team providing online educational services.

$$AdverEdu = Platform, Post, Member, Team \tag{7}$$

where *Platform*—platforms of social media on the Internet where virtual communities are created for advertising activities of web projects that provide educational services, *Post*—information content of virtual communities, *Member*—users of virtual communities of social media on the Internet, *Team*—the team of executors of the educational web project (including moderators and administrators of virtual communities).

$$Platform(AdverEdu) = \{Platform_i(AdverEdu)\}_{i=1...N^{Platform}} \tag{8}$$

where $Platform_i$—is the i-th platform on which the advertising activity of the educational project is carried out, $N^{Platform}$—is the number of platforms of the educational web project.

$$Post(AdverEdu) = \{Post_i(AdverEdu)\}_{i=1...N^{Post}} \tag{9}$$

where $Post_i$—is the i-th post published during the implementation of the educational web project, N^{Post}—is the number of posts of the educational web project.

$$Member(AdverEdu) = \{Member_i(AdverEdu)\}_{i=1...N^{Member}} \quad (10)$$

where $Member_i$—is the i-th user of the social network in which the educational web project is implemented, N^{Member}—is the number of users of the social network.

$$Team(AdverEdu) = \{Team_i(AdverEdu)\}_{i=1...N^{Team}} \quad (11)$$

where $Team_i$—is the i-th member of the educational web project team, N^{Team}—is the number of members of the educational web project team.

6 The Main Stages of Creating an Educational Web Project

In order to achieve the goals and objectives of the project, it is important to follow the rules of its implementation, so Fig. 5 shows the stages of creating an educational web project.

The planning stage is the first stage when the idea of creating an educational web project arises. At this stage, the goal, purpose and objectives of the web project are formulated, in particular:

The topic and specialization in which subject area the educational web project will be implemented is determined.

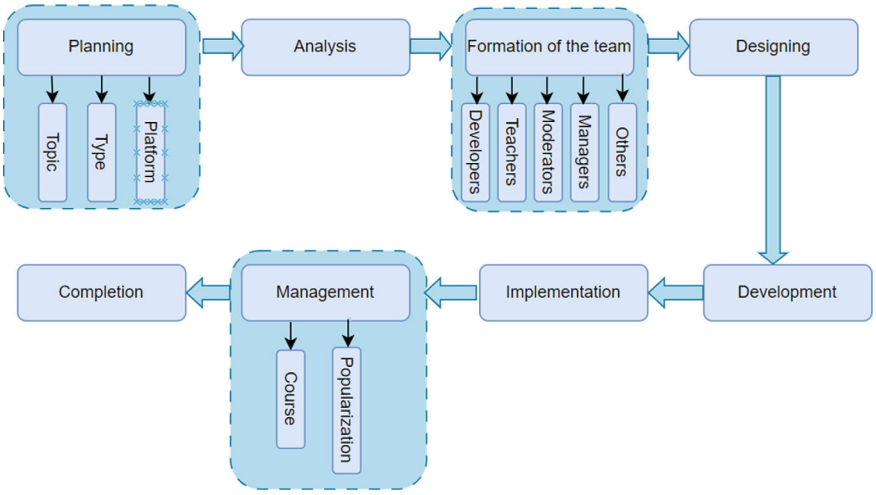

Fig. 5 Stages of creating an educational web project

The type is determined, namely, whether it will be a web project that provides online educational services or a web project that promotes offline educational services.

The list of platforms on which the educational web project will be implemented is determined, for example: website, application, social networks, messengers, etc.

The analysis stage is the stage of analysis of an educational web project, which, given the rapid development of social media on the Internet, should be carried out continuously and in different key segments. In general, the initial analysis includes: analysis of the chosen topic (subject area) of the web project being created, analysis of existing and reference educational web projects, analysis of the market, target audience and competitiveness, analysis of hardware and software for the web project. However, for a deeper and more permanent analysis of social media pages created for advertising and branding of educational services, the following parameters should be analyzed:

- page design and page content;
- the design of the page, namely the profile name, profile header and avatar, visualization of posts in all social networks should be the same for better visual recognition of the brand of educational services;
- content of social media pages;
- It is important to take into account the content in accordance with the chosen social media, the content and style of posts, the frequency of posts and stories. It is also important to analyses the perception of content by the target audience in different social networks;
- target audience.
- It is necessary to analyses the involvement and activity of the target audience in social media of educational projects. It is important, especially in advertising activities, to analyses the authenticity of participants in social media. It is necessary to regularly analyses feedback from the participants of the educational web project, both those who are taking part in training and those interested in advertising;
- analysis of competitors and reference educational web projects;
- It is important to analyses their information content, subscribers, advertising of their pages and educational services in general. It is also necessary to analyses competitors' social media strategies, methods and tools for promotion.

Team formation—at this stage, the team that will be responsible for the implementation of the educational web project is formed. It is important to identify the web project manager and the heads of individual key activities. The following team members are important in the formation of an educational web project:

- Managers are, in particular, the main manager responsible for the success of the web project, managers of functional tasks, managers of social networks to promote the educational web project.
- Developers—include: software developers (websites, applications) for the provision of online educational services, developers of content for advertising educational services (e.g., SMS managers, story makers, video operators, etc.).

- Teachers—if you are implementing an educational web project that provides online educational services, you need a team of teachers who will create educational materials in their disciplines (lecture notes, video lessons, live broadcasts, etc.).
- Moderators are those performers who are necessary for the implementation of an online educational web project. Moderators will be responsible for communication and interaction with the participants of the educational process.
- Other team members are formed depending on the specifics of the educational web project being created.

Design is the stage of developing the architecture of a web project and the brand book of an educational web project. When it comes to presenting an educational web project on social media, it is necessary to develop the information content and the main content of the pages (avatar, profile picture, highlights, pinned posts, etc.) in accordance with the branding of the web project. If you need to create a web application or website, we design the software and website structure.

Development is the activity and processes that are aimed at developing the applications, websites, pages, etc. that we need, in accordance with the tasks and algorithms designed at the design stage.

Implementation is the stage of launching a ready-made educational web product for free access. Recruitment of participants for training or groups to advertise the educational web project.

Management is the stage of development, management and support of an educational web product. This stage, depending on the type of web project, includes course management and project promotion.

The course management team provides technical support and communication with the participants taking part in the training.

Promotion management involves managing virtual communities and pages created for branding an educational web project.

Completion—the stage of completion of an educational web project is considered to be the completion of online courses or the closure of an educational institution that has been promoted through social media [23].

7 Requirements for Creating an Official Page to Promote an Educational Web Project on Social Media

The appearance of the main page of an educational web project on social media is one of the elements of advertising and branding. The requirements for official pages of educational web projects are different from ordinary pages of goods or services, it is necessary to take into account the specifics, target audience, and often the requirements of the governing bodies of educational institutions.

Thus, the requirements for creating official pages of educational web projects on social media are as follows:

- the page logo on all social networks should be the same and match the brand book;
- the name of the page with the affiliation to the educational institution;
- information about the educational web project ("header" of the profile) with the following data: page title, name of the institution, abbreviation, website, address, telephone number.

Information published on the official page of an educational web project on social media must meet the following requirements:

- comply with the content plan agreed in advance with the manager;
- should relate to the educational web project and its main activities;
- be diverse (use all types of content, such as entertainment, informational, user-generated, interactive, advertising);
- use hash tags.

8 Algorithm for Choosing a Platform for Creating an Educational Web Project

When creating any type of educational web project, the choice of platform is an important task. It is worth noting that when implementing web projects that provide online educational services, advertising activities will also be carried out on the platforms of social media. Therefore, in this type of educational web project, it is possible to combine platforms for creating training courses (as described above, for example, applications) and social networks for creating virtual communities to position their educational services and products [24].

Figure 6 shows the algorithm for choosing a platform for creating an educational web project.

An important stage of the algorithm is the creation of course content and filling the selected platform with it.

9 Algorithm for Creating Information Content to Promote an Educational Web Project in Social Media

It is important to promote a web project in social media on the Internet to create and publish the right content in accordance with the chosen platform.

The algorithm for creating information content to popularize an educational web project in social media on the Internet is shown in Fig. 7.

First of all, you need to define the goals of creating content, i.e., the purpose of its creation. Next, you need to choose one of the types of content, namely: informational, advertising, entertainment, user-generated and niche.

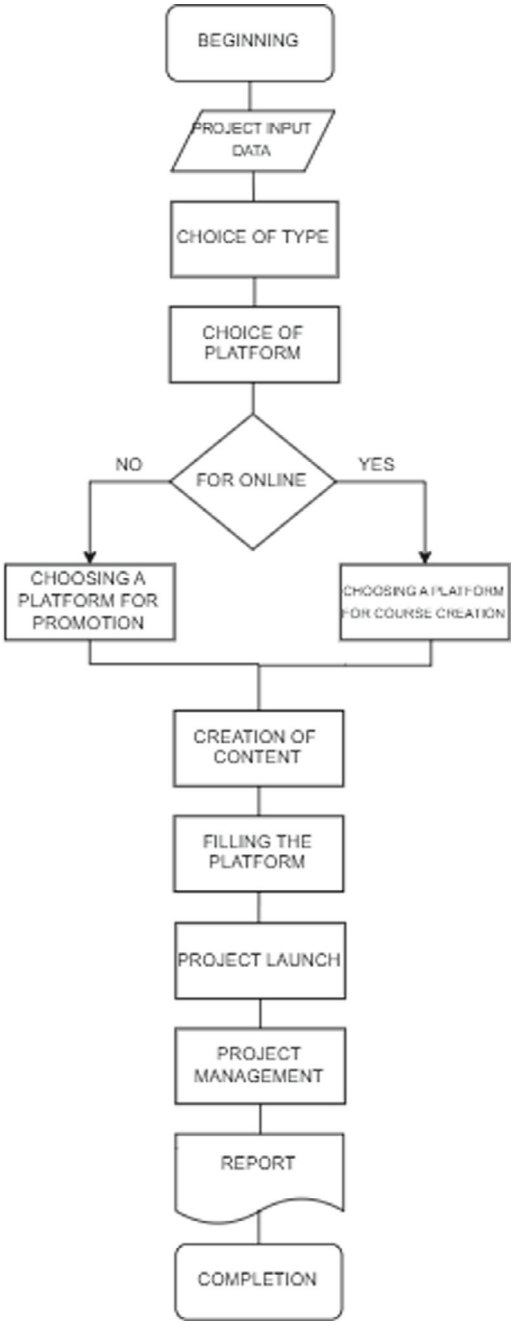

Fig. 6 Algorithm for choosing a platform for creating an educational web project

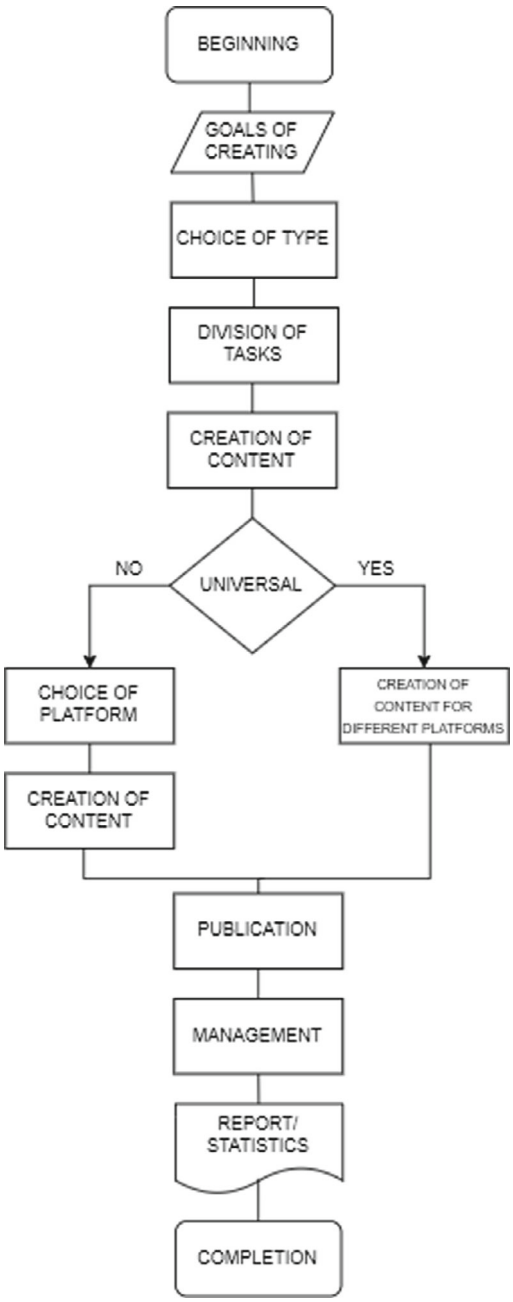

Fig. 7 Algorithm for creating information content to popularize an educational web project in SEI

The distribution of tasks for creating a post by the manager is necessary for the high-quality creation of information content, as the post consists of several parts, namely text and visual. Often, experts in the relevant field (photographers, videographers) are invited to create high-quality visuals. And they specify in the task what exactly the post should include.

The next step is to determine whether the post is made universal (the same) for all platforms where the educational web project is hosted, or whether a separate post is created for each platform (social network), or a universal post with different technical characteristics. After the content is published, it is managed and statistics are monitored to allow for further analysis.

10 Results of Managing an Educational Web Project that Advertises Educational Services

A department of a higher education institution, namely the Department of Social Communications and Information Activities of Lviv Polytechnic National University, was chosen to present the results of the educational web project advertising educational services. The Department of SCDI provides educational services for students in the specialty. 029 Information, Library and Archival Affairs according to the accreditation by the National Agency for Quality Assurance in Education.

For advertising activities, the management of the department chose to create official virtual communities in two social networks, namely: Facebook and Instagram, and appointed two employees responsible for managing these virtual communities.

The content relates to the activities of the department during the academic year (September-June), which includes posts about events, useful information, urgent announcements, etc. And the information content related to the department's advertising to attract new students, most attention is paid to such information content during the admission campaign (July–August).

Official pages of the Department of Social Communications and Information Activities of Lviv Polytechnic National University in social media [25, 26]:

- Facebook: https://www.facebook.com/SCIADepartment
- Instagram: @skid_lpnu.

The choice and publication of information content on social media is based on the audience that is registered there. The social network Facebook (Fig. 8) has older participants, mostly graduates, parents of students and potential applicants.

According to the statistics, it is noticeable (Fig. 9) that the participants in the Instagram social network are younger, respectively, our students and applicants.

During the 2024 admissions campaign, a universal advertising post was created for two social media platforms and published simultaneously.

The posting on Facebook and Instagram is shown in Figs. 10 and 11, respectively.

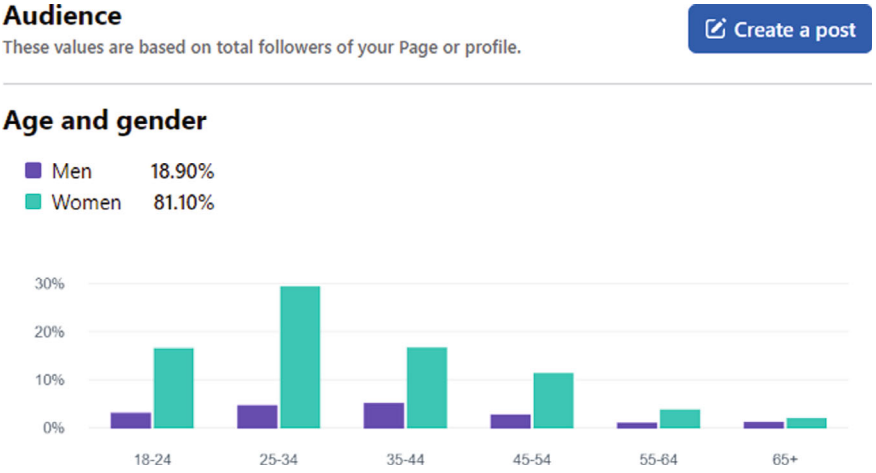

Fig. 8 Statistics of community users in the social network Facebook

Fig. 9 Statistics of community users in the social network Instagram

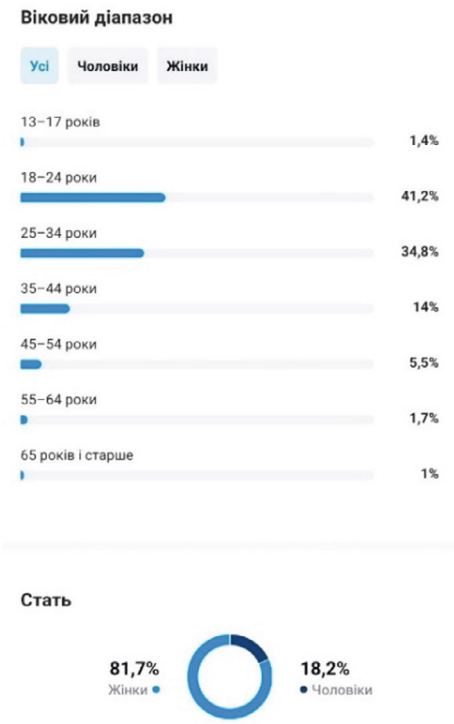

Fig. 10 A post in the social network Facebook

Figures 12 and 13 show the statistics of posts on Facebook and Instagram, respectively. Posts on both social networks were promoted on a paid basis. However, each social network had different parameters for setting up advertising promotion, depending on the characteristics of the platforms, target audience, and requests for expected results. Figure 12 shows the statistics of a post on Facebook, namely, general statistics and statistics of two paid integrations on two days.

During the active phase of the admission campaign, the following amount of content was published on the official pages of the Department of Social Communications and Information Activities of Lviv Polytechnic National University:

- 4 vocational guidance posts, i.e. advertising type of information content;

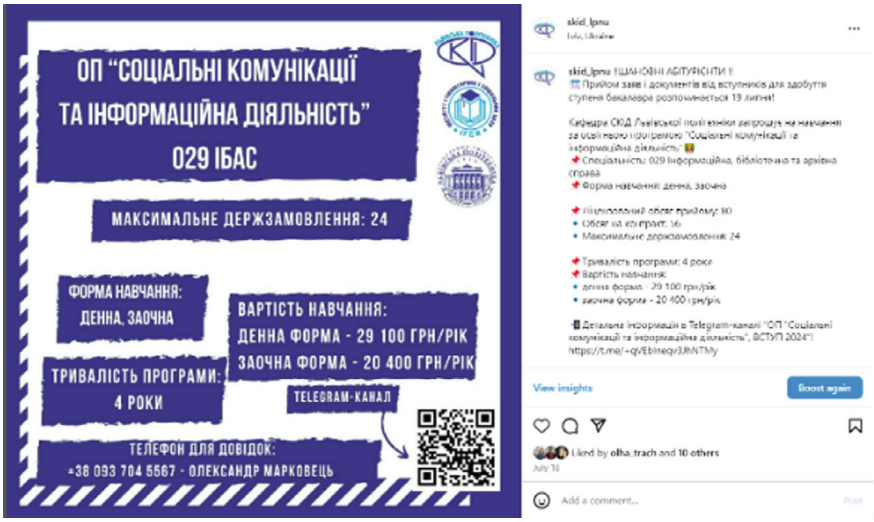

Fig. 11 A post on the social network Instagram

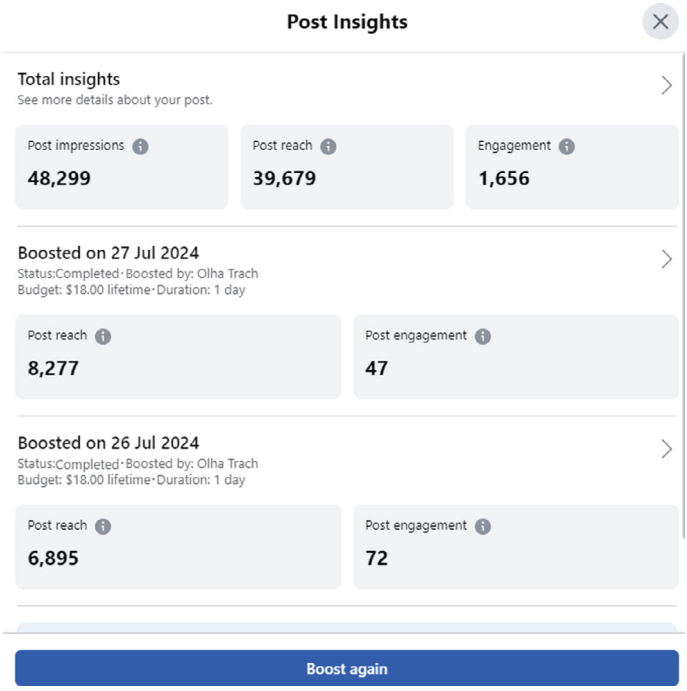

Fig. 12 Statistics of a post on the social network Facebook

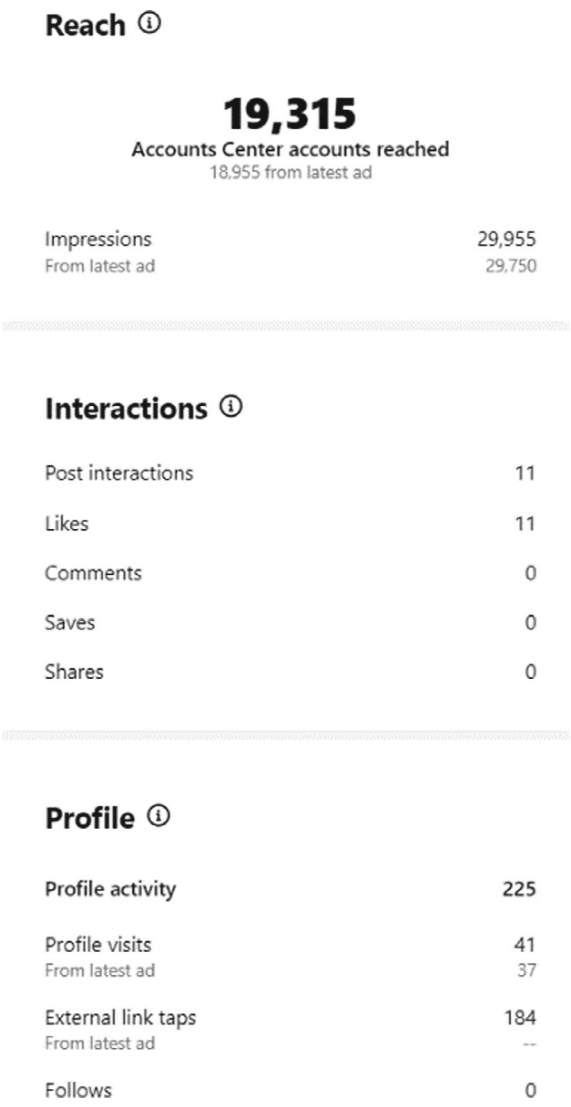

Fig. 13 Statistics of a post on the social network Instagram

- 2 posts in the format of entertaining videos, i.e. entertaining type of information content;
- 1 news item.

In addition, we reposted posts of various types of information content on the available content on social media.

Figures 14, 15 and 16 present a comparative analysis of identical posts from two social networks, which includes such characteristics as:

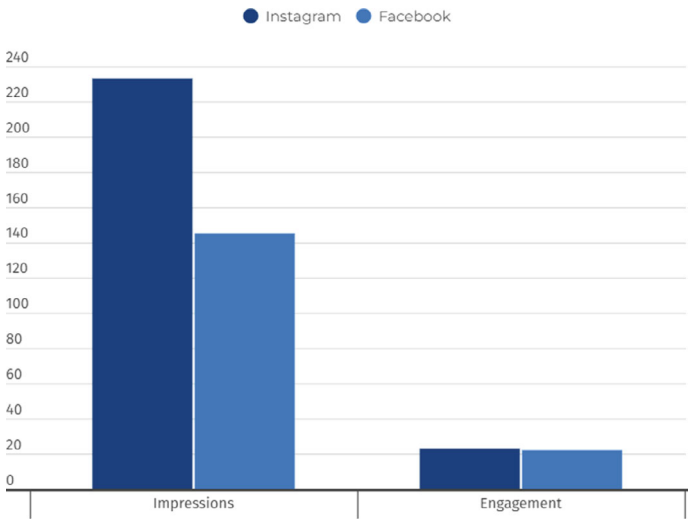

Fig. 14 Statistics of one news post

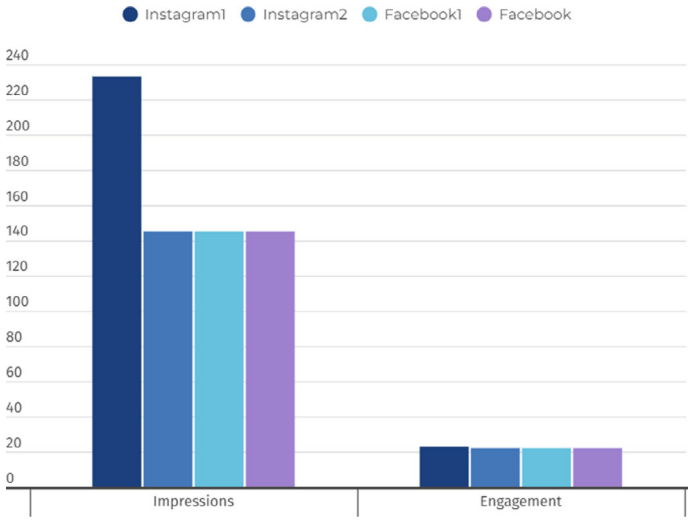

Fig. 15 Statistics of two entertaining posts

- reach—the number of social media users who viewed the post
- Interaction—the total number of interactions with a post, including likes, comments, and shares.

Figure 14 compares the information posted about the top 10 motivational books. Figure 15 shows a comparison of two entertaining posts posted as videos.

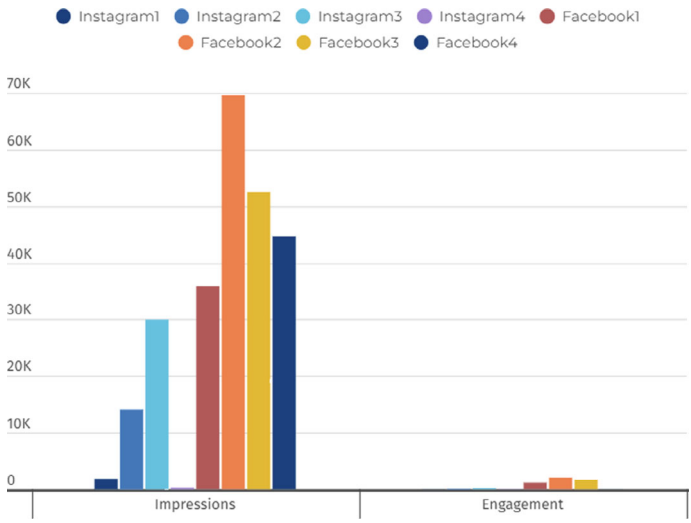

Fig. 16 Statistics of four career guidance posts

Figure 16 presents a comparative description of 4 posts of career guidance activities from two social networks Facebook and Instagram.

11 Conclusions

The article defines types of educational projects: web projects that provide educational services online and web projects that advertise educational projects. The main characteristics and types of educational web projects are described to better understand the need to create different educational projects and promote education in social networks. Platforms in social media for creating educational web projects are identified. The requirements for creating an official page to promote an educational web project in social networks are determined. The algorithms for creating information content for promoting an educational web project in social media and choosing a platform for creating an educational web project are presented. The results of an educational web project advertising educational services are presented in the example of a department of a higher education institution, namely, the Department of Social Communications and Information Activities of Lviv Polytechnic National University.

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Relevance and Exhaustiveness of People Analytics Topic in Scientific Research—Multiple Aspects Examination

Zuzana Takacsova and Filip Petrinec

Abstract This paper aims to examine the relevance and exhaustiveness of the People Analytics topic in scientific research. Multiple aspects of each publication are analysed and evaluated against determined scope and details about all retained publications are available as a supplement of this article for reference. This article displays the evolution of the topic over time based on the frequency of publications and popularity of this topic at Google Analytics, identified the most influential authors, and captured the context of the research based on the publications' titles. The methodological approach (including hybrid non-empirical and empirical methodologies) and the most touched topic are assumed for each publication. Thus, based on the frequencies are visible most popular topics and areas. On the other hand, rarely found issues or disproportional frequency of a particular methodology provide a hint, where can be further research focused. Overall, this study confirms the increasing popularity of People Analytics in the business and scientific world and provides hints what areas, topics, and methodologies might be an exciting addition to existing research.

Keywords People analytics · Human resource management · Workforce analytics · Literature analysis

1 Introduction

Digitization and rapid increase of available data affect many domains, including human resources. In the competitive business world, understanding data and its usage are fundamental for the success of many companies. At the same time, the most valuable assets for the company are undoubtedly employees. As Lithikar and Verma

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[80] stated, "the concept of data analytics in HR management is increasingly gaining attention and popularity among consultants and practitioners in the field of human resource management." Andersen [3] acknowledged that "HR analytics is still a fairly immature field and has not yet reached its full potential." Therefore, there is still space for developing all analytical stages—starting with descriptive analysis, through advanced and predictive analytics, towards insightful prescriptive analytics.

Demand for understanding workforce behavior in the context of changing world led to the need for continuous development of supportive tools and methodologies that "can be used both to measure the impact of your organization's investment in leadership development and, perhaps more importantly, to improve the return on that investment" [9]. Without any doubt around the importance of People Analytics, there is a wide range of topics and questions about employees to be examined, measured, and monitored. The role of HR and analytics [4, 7, 21] starts at the beginning of the employee journey—in the recruiting stage. As Linley [81] highlighted, "finding hidden talent and empowering social mobility widen the opportunity for all people, particularly those from diverse backgrounds, it allows the identification and recruitment of people who demonstrate grit, resolve and tenacity, who might otherwise have been excluded by arbitrary recruitment barriers." Once a person is hired, the employee lifecycle starts, and his demographics, inclusion and performance need to be stored in the data [43], measured [15, 17, 38] and monitored. In the era of gender equality and multicultural society, measuring workforce diversity is an essential goal within HR and proper talent acquisition and management [53, 103, 116]. Understanding what skill set is required and a future-ready set of skills is crucial for employee matching and suggesting their potential development plan. Behavioral traits and culture in the company provide additional space for advanced analytics [73, 83, 87] and ML—agility, collaboration, integrity and other ambitions can be examined and measured to reflect on the company imperatives in reality. Finally, the last stage of the employee life cycle is voluntary or involuntary leaving of the company. To mitigate the risk of losing valuable and talented employees and build business continuity in a company, the probability of leaving and factors that increase chances of staying might be relevant insights.

From the perspective of service science, People Analytics might include the following services [156]: Information-as-a-service, Data-as-a-Service, Analytics-as-a-Service and Insights-as-a-Service. The ownership of particular stages and their importance depend on many factors, starting with the size of the company, geographical footprint, business domain, available financial, continue with the information system of the company and available employee-related data and its company, ending with legal and compliance topics regarding data usage as well as its interpretation.

Similar to Scholz [123], multiple authors evaluated the current coverage of PA in scientific literature as insufficient and concluded that more research is needed. In addition, the modern technological environments [6, 8, 19, 20, 42, 51], Internet of Things [5], Data from communication platforms [27, 69, 84, 144] play a role in many domains and require attention in this field [23, 33, 37].

2 Relevance of People Analytics

A starting point of this research was to examine the popularity of the People analytics topic by using Google Trends [45–48]. The popularity in Google Trends is derived from the number of searches. Within Google trends is possible to determine the scope of review by setting up the filters for countries, timescale, categories and type of search, where have been keywords used (Web, Youtube, Image and News Search, or Google Shopping. Google does the categorization of topics based on the context. For the overall popularity of the terms: [40, 41, 50, 61] People Analytics, Workforce Analytics [115, 129, 142, 157] and HR Analytics [21, 52, 65, 78, 85, 95, 114], we have started by looking worldwide across all categories, including all web searches (Fig. 1). "Numbers stand for search interest relative to the highest point on the chart for the given region and time" [44]. To interpret results, 100 means the peak and 50 means halve of popularity compared to the peak for the term. Insufficient data for the term are represented by 0.

The interest over time in People Analytics, HR Analytics, and Workforce analytics confirms the PA topic's novelty in the context of science and the general knowledge and its increasing popularity over recent years. HR Analytics [102, 138–140, 146, 153] is a more common term than People and Workforce analytics. Comparing the dominant term used by region, we could see in Fig. 2 that HR Analytics is more frequent than Workforce and People Analytics in most areas. However, in Latin and South America, Japan and North Europe is the most famous People Analytics.

By reviewing details of each term, we have identified Workforce analytics [31, 32, 76, 108] to be most popular in Australia, the US, Canada, India and UK. In the most common related queries of each of these three terms, we could see the other two. Therefore we can conclude that these terms are often combined in the searches and might be synonyms.

Looking exclusively on Slovakia country, across all topics within Google trends, there hasn't been enough traffic since 2004 until nowadays that any of the terms could be displayed on the chart (Fig. 3). Arguing with the size of the population

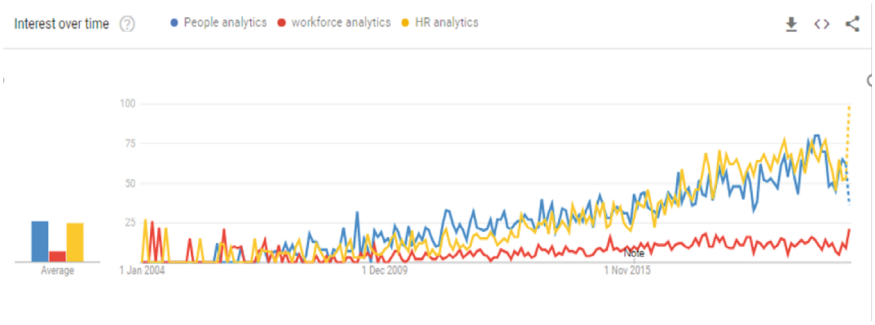

Fig. 1 Interest in people analytics, workforce analytics and HR analytics over time. *Source* Google Trends, 2021a

Fig. 2 People analytics, workforce analytics and HR analytics, footprint across the globe. *Source* Google Trends, 2021a

in Slovakia would be meaningful. However, spot-checking two similarly populated countries like Switzerland or Norway as an example has shown enough search events for google trends. In our neighboring countries, the Czech Republic, Ukraine, Austria and Hungary also haven't had enough results to display. On the other hand, in Poland was enough data to show trends.

Additionally, we have reviewed the Science separately and Business and Industrial to get a proportionality of these categories in the search context (Figs. 4 and 5). Unfortunately, it is impossible to choose a combination of categories in the current version, only one specific category or all. We have looked for the most recent five

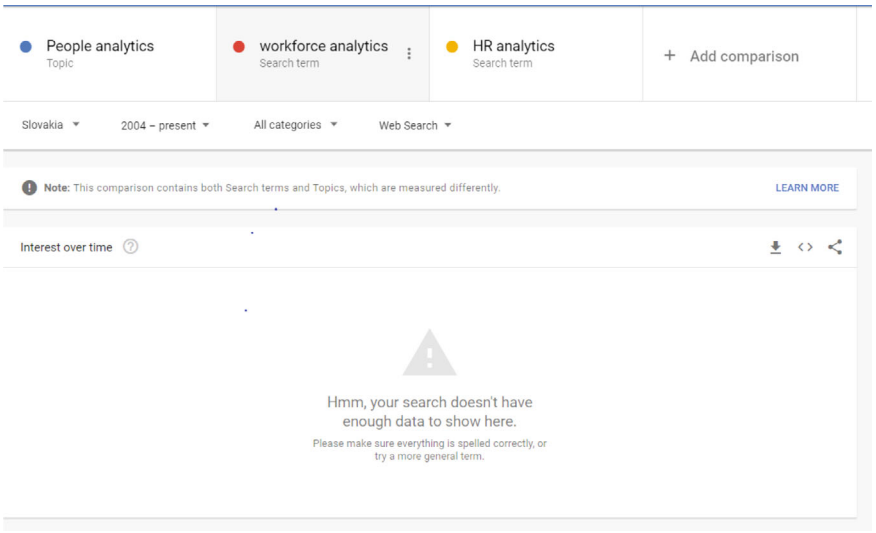

Fig. 3 Popularity of people analytics over time in Slovakia. *Source* Google Trends, 2021b

years to see if there were no particular peaks; more seems to be seasonality within a year in the research trends.

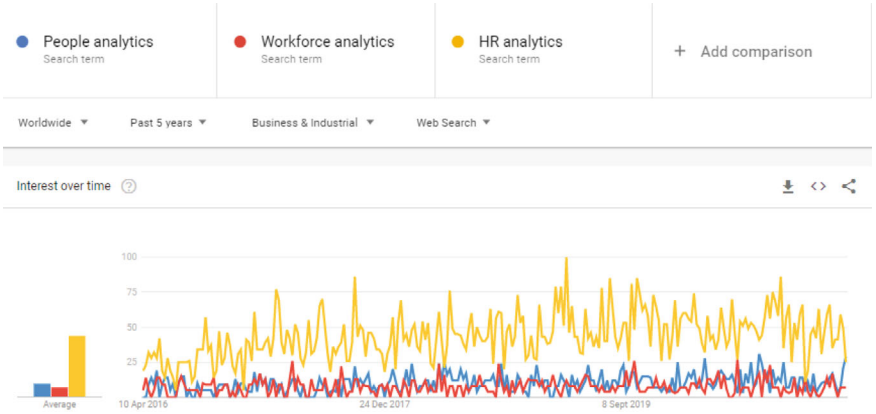

Fig. 4 Interest over last 5 years in PA relevant searches in business and industrial category. *Source* Google Trends, 2021c

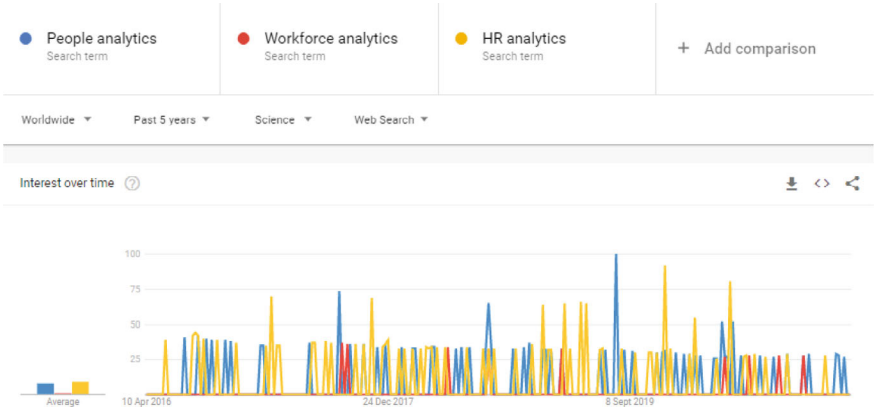

Fig. 5 Interest over last 5 years in PA relevant searches in science category. *Source* Google Trends, 2021d

3 Examination of People Analytics by Extensive Literature Review

3.1 Scope of the Non-empirical Review and Research Questions

What are the key research topics and areas where PA services can be utilized? The respective terms—keywords used to identify studies relevant for this research were People Analytics, HR Analytics [34, 49, 88, 89, 98, 102], Workforce Analytics, Human Resources Analytics, HC Analytics and Human Capital Analytics [22, 56, 57, 79, 94, 96, 111, 112, 121, 122]. The search has also been performed contextually in the case of the concrete subdiscipline of People Analytics [127, 130, 131, 141, 143]. The primary source databases were Google Scholar, SpringerLink, ISI Web of Knowledge (Publons), IEEE Xplore, ScienceDirect (Elsevier), Taylor & Francis, JSTOR, ACM, Emerald, Scopus, and Willey. During the review of retrieved publications were also identified additional publications based on the references.

The exhaustive research has been conducted; however, the overall completeness of the collection cannot be guaranteed. To help determine what topics are relevant for people analytics, conceptually describe the scope and key topics covered by People analytics, such as Isson et al. [58]. Due to the complexity of the People analytics topics, articles with the main focus on Strategic Workforce Planning [10, 12] have been de-scoped from this review. Strategic Workforce Planning, also called Strategic People Planning [77], might be part of the People Analytics service portfolio [135]. However, the topic is very complex—due to combining people data with business planning, demand–supply [91], financial, and cost planning [90]. Therefore, it can even be the target of a separate literature review. In addition, topics of automation or optimization of HR information systems are topics where People analytics services might interact, which are not in the scope of this review.

A detailed table contains publications that are also available with their particular attributes: author, title, year of publication release, key topic area, methodology, outcomes, publication name. We have used these attributes to analyze the publications and evaluate them chronologically or cluster them into different categories. The concept has been inspired by a systematic literature review introduced by Kryvinska et al. [74].

Following research questions were developed to be examined:

What is the popularity and relevance of topics of People analytics services over the years in scientific research?

Is the research around this topic already exhausted? What is the assessment provided by other researchers on the literature extensiveness in the field of People Analytics?

What methodological approaches are used most and least frequently in the PA-relevant publications?

What are the key research topics and areas where PA services can be utilized?

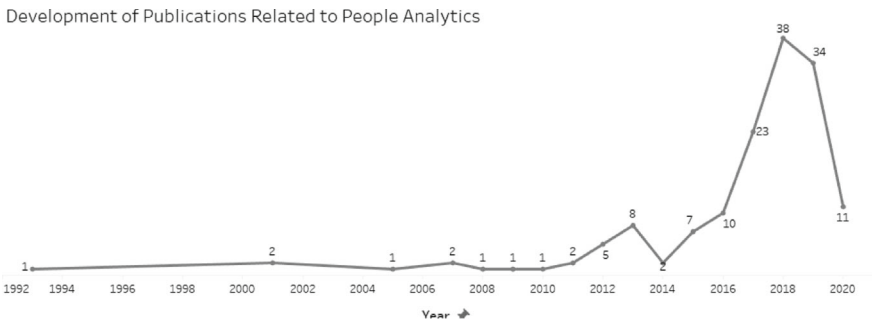

Fig. 6 Development of people analytics relevant publications over time

3.2 Research Trend Over Years Related to People Analytics Services

We have reviewed 149 publications that have been closely related to People Analytics, resp. to HR Analytics. The frequency of using different naming has also been evolving. For example, the term People Analytics in the title of the publication appeared first in 2013 and then from 2017 have been used frequently. As the total pioneer also cited in other publications in scope, we have chosen the article *Optimal Evaluation Policies for Workforce: A Bayesian Stochastic Model* [35]. This article introduces workforce analytics performed by the application of statistical methods to support employees' performance management.

It took almost a decade within our pool of publications to see the workforce analytics topic. The following relevant studies were found in 2001 when both were case studies examining employee turnover. By observing the trend line displayed in Fig. 6, we have learned that the evolution of People Analytics over time was prolonged, and a few studies were published till 2014. As a result, we have seen a significant increase in the PA-relevant literature (literature review has been conducted and refreshed in the first months of 2020).

The most significant popularity of the topic was observed in 2018 when the PA services in companies started to be established. We have identified a high proportion of empirical studies, including specific case studies, the employees' or company survey data and/or experimental research, application of mathematical/statistical models [100, 101], and non-empirical. Detailed analysis of methodologies can be found in 3.4.2.

3.3 Authors

A significant number of different authors have been identified during this review, with a global footprint. As the topic of PA is multidisciplinary itself, the authors

from other areas of expertise may contribute to this topic. There have been identified 44 publications written by a single author and 44 by two authors. The maximum number of authors who participated in a publication was 7 in the book *Analytics-Led Talent Acquisition for Improving Efficiency and Effectiveness* published in 2019. Pawar and Jain are coauthors figuring as well in other publications from the People analytics field. A. Jain has been involved in 4 PA relevant publications: In the initial performance management from 1993 [35], then retained in the talent management topic and predictive analytics [106] and [60] and also participating in the prediction of attrition rate [155]. Pawar has participated in 2 more publications where have been applied text analysis for mining performance appraisal for performance management and in CV analysis [1, 28, 105, 120] to support recruiting. Based on the number of publications relevant for this research (Fig. 7), together with authors Sripathi, Madhavaiah and Varshney, they are the top authors.

Sripathi and Madhavaiah have been focusing more on general People analytics topics, the position of people analytics in the era of digitalizing and big data [18, 26, 55, 137], and the effectiveness of HR metrics [14, 16, 36] and HR analytics in the HR evolution. Varshney has coauthored the experimental research focused on talent [93, 133, 149, 158] and employee behavior, bringing insights to improve job transfers by matching employees [107, 152] with positions [66, 72, 104, 125], predicting employee expertise [92, 132, 147] and, in general, understanding their behavior based on the big data available [39, 64, 124, 154].

There are other influential authors of book sections, conference papers, journal articles. Particular attention should also be granted to whole books about People analytics [3, 41, 71, 126, 127, 143], resp. role of big data and analytics for successful HR management [134, 145]. Smith [135], in the book *HR Analytics: What, why and how together* with Waber [148] in *People analytics: How* social *sensing technology will transform business and what it tells us about the future of work,* comprehensively describe people analytics, from the role, purpose, through various case studies and implementation hints for companies. Book *Fundamentals of HR Analytics*, written by Diez et al. [30], aims to help become more analytical in HR. Scholz [123] brought

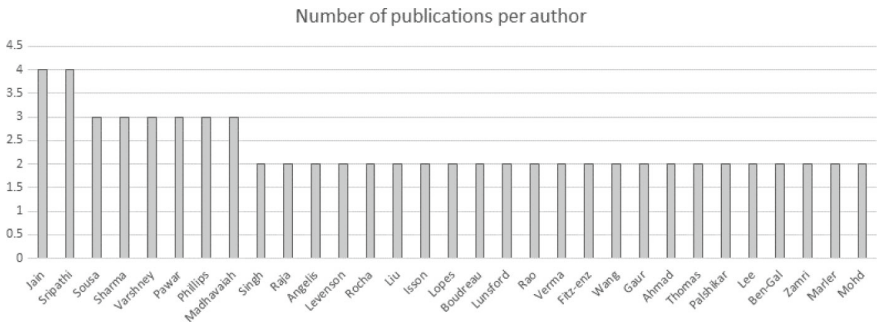

Fig. 7 The number of PA-relevant publications of authors who published more than one publication in the PA area

another complex overview in the book *Big Data in Organizations and the Role of Human Resource Management* [97, 118, 161]. The book *People Analytics in the Era of Big Data: Changing the Way You Attract, Acquire, Develop, and Retain Talent*, written by Isson et al. [58], provides a general overview with a focus on talent acquisition and employee retention.

3.4 Titles, Topics and Challenges

By reviewing, clustering, and analyzing various publications related to People analytics, could be found different topic areas on which authors have been focusing. Frequent topic interlinked with the challenge was the integration and enabling of analytics in HR management, establishing analytics and employee relevant metrics into the standard daily business of company and support decision making [98, 136, 137]. Self-explanatory intentions of many publications, such as the book *HR Analytics: The What, Why and How?* by Smith [135], and studies as *1* [13] signalizing the need to justify the purpose of PA services, define the operating model, and try to find a way for easy adoption by HR.

Numerous studies with concrete analytics subjects focused on helping talent management, and retention of the workforce, diversity, recruiting services, and analysing employee behavior, their traits and their values (e.g., collaboration [150], attitude, empathy, agility) are also in great attention. It would not be a piece of surprising information that the ethics and policies need to be evaluated to execute specific analysis by using employee-related data. To review the privacy and legal aspects of using employee-related data, presenting the results, and deriving action steps based on the analysis results might be necessary when running PA services. Publications as [128] and [126] supply a detailed investigation on this topic. Looking at the trends and words used within the titles themselves, Fig. 8 displays the word cloud consisting of meaningful words used in the titles and can provide the notion of titles.

3.5 Analysis of Research Methodologies

3.5.1 Categorization of Approaches

This subchapter examines the research approaches of authors. All publications' research approaches were classified into six categories (adapted from Kryvinska et al. [74]) and represented by the diagram in Fig. 9. The original methodology was developed for a literature review of servitization problematics. Based on the similar nature of the topics, only a few adjustments were necessary to fit our purpose.

Both empirical and non-empirical methodologies have been further examined and clustered under displayed subcategories. In the source were all publications sorted

Fig. 8 Word cloud of publications' titles

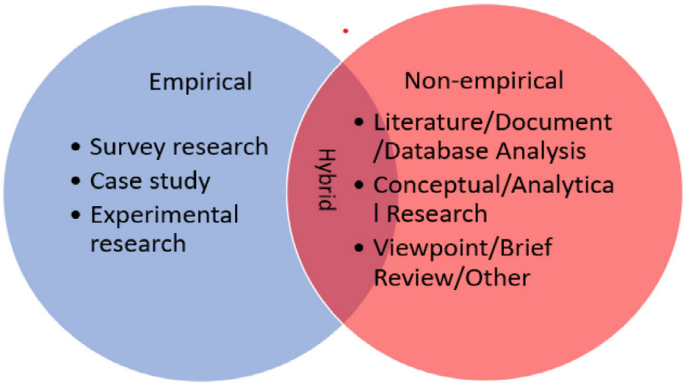

Fig. 9 Categorization of research methodologies derived from [74]

into two categories—empirical and non-empirical. In the praxis have been frequently identified multiple approaches within one publication. This situation will be reflected in the following chapters as a 'Hybrid' methodology—when in the research were used both Empirical and Non-empirical methods.

During the review of empirical studies were identified three systematic approach categories were:

- First, survey research is "a primary data-collecting approach in which people are surveyed, and the responses are recorded for further, quantitative analysis" [11]. Into this category falls various survey methods starting with personal, phone and video interviews and web-based surveys.

- Case study research is an approach that "allows investigators to retain the holistic and meaningful characteristics of real-life events" [159]. This article has also included concrete company-based research papers, where authors deal with specific company situations, challenges or use company-specific data.
- Experimental research category includes studies with manipulation of independent variables. Based on Kryvinska et al. [74] in these publications, "is looked at how humans respond to the change of the independent variable." An example of this approach is scenario-based role-playing, where the researcher simulates the scenario and captures the results. In addition to the original scope, including deployed statistical models or innovative applications of statistical methods, artificial intelligence [2, 70, 82, 110], and machine learning [54, 68, 75, 86, 120, 132].

During the review of empirical studies were identified three frequent approach categories were:

- Literature and database analysis [119] is the first subcategory of the non-empirical methodological approaches. Even though this category processed already existing publications, these studies may lead to interesting findings. Following the explanation of Webster and Watson [151], "it facilitates theory development, closes areas where a plethora of research exists, and uncovers areas where research is needed." An output of literature and database review might be "records like documents, reports, manuscripts of even visual materials can be made" [117].
- Another broad non-empirical subcategory includes conceptual and analytical studies. As described by Jarvinen [63], "conceptual-analytical studies are either set up to derive theory, models or frameworks, or to analyze the basic assumptions that underlie previously presented theories, models or frameworks." Definitions, conceptual models, comparisons of methods, classifications, action steps are specific content and output of these studies.
- Remaining non-empirical studies relevant for this research landed in category other. Good examples in this category are viewpoints as well as brief reviews. During this review have also been found multiple commentaries. These commentaries have been excluded from the scope as the reviewed sample did not bring much additional information or innovation to the PA field.

3.5.2 Analysis of Aggregated Findings

When analysing the nature of the studies, it can be deducted from Fig. 10 that there is a similar proportion of usage empirical and non-empirical methodologies (36% vs. 40%). The hybrid category, which was created for purposes of this literature review, was meaningful as 24% of studies have a mixed methodology.

Overall proportions have shown a relatively good balance of the empirical and non-empirical studies. First publications have used an empirical approach (experimental and/or case studies), as per Fig. 11, their peak was in 2018. From that time, the dominant studies were non-empirical, mainly conceptual. As DiClaudio [29]

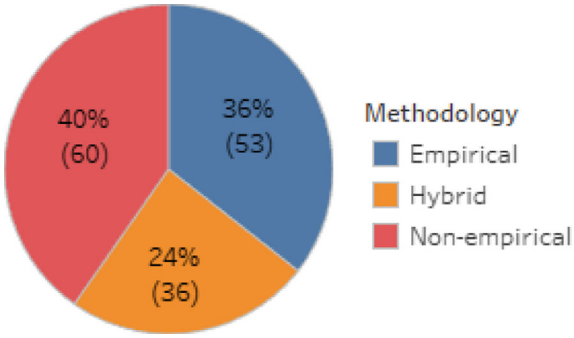

Fig. 10 Number of empirical, non-empirical and hybrid PA publications

emphasized, "with the competitive landscape changing at an ever-faster rate, it has never been more challenging to plan workforce composition or predict future talent needs. Technology is not only spurring the evolution—and sometimes the destruction—of business models and industries but also changing the role of humans in the workplace. 99" Therefore, the recent popularity and change of the role might also be the contributors to the need for conceptual analysis of PA services, defining the role and operating model. The hybrid studies were on peak together with the rest of the studies, following the trend of the whole topic. With a conceptual framework of literature review, the authors introduced the topic and then performed a survey (9) or focused on the detailed case study (17).

Looking at the detailed approaches applied in the studies, the most frequent is conceptual research (Fig. 12). However, in many cases, when authors used conceptual/analytical approaches, other approaches have been applied. Purely conceptual/analytical have been 23/74 of the studies, remaining 51 have used a combination of conceptual with another approach. A non-empirical combination, we could see literature review to be the backbone of conceptual research. Hybrid methodologies have been in the case of complex publications, often having conceptual approaches combined with case studies, backed up by experimental research or survey.

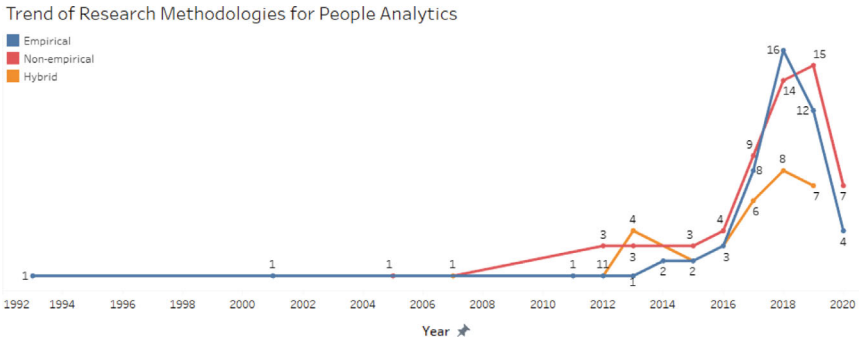

Fig. 11 Trends of research methodologies over time

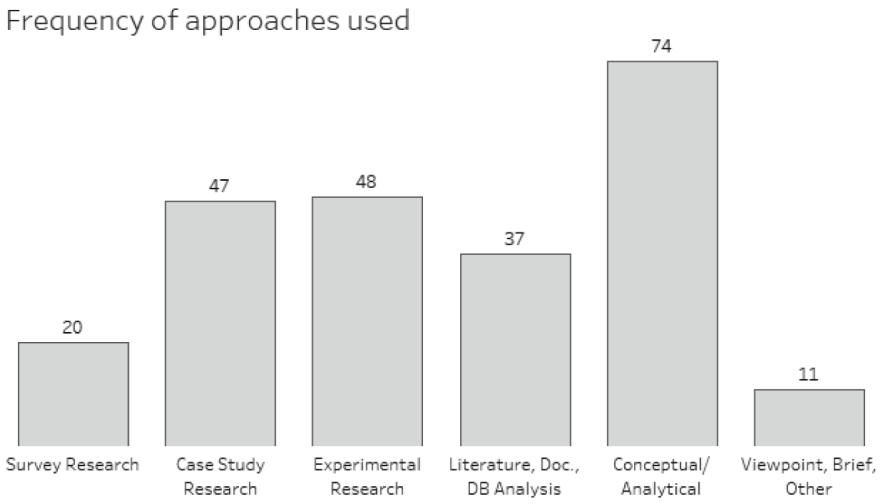

Fig. 12 Detail of frequencies within different methodologies

The second and third most frequent approaches are the case study (47 publications) and the experimental research (48 publications). Deriving from the fact that the PA field is relatively new, involving the HR domain and IT and business management, there is massive potential for experimenting and case studies was also emphasized by Yoon [160]. Application to the commercial business world seems to be very important in the PA field. What might be caused by overall novelty in the commercial and scientific world and research aims to reflect and support raised business challenges. The least frequent field was the viewpoint, brief and other. It might be caused by setting this research not to include Commentaries and short insights as by pre-reviewing this category of information sources.

3.6 Output

As can be seen, the approaches taken had been relatively equally on the side of empirical methodologies as well as non-empirical. Authors have been using different combinations of approaches, and in 24% of the publications, they have combined both empirical with non-empirical methodological approaches. The output of conceptual and analytical research can be a concept or business model proposal, set of principles, new frameworks, recommendation of actions to be taken, evaluations, or new definitions. On the other hand, in the experimental studies, one can find the statistical model [25, 68], mathematical model, or framework to process data to support HR Management [59, 67]. The following section briefly mentioned the origin of these publications in terms of journals and a detailed review of different topic areas and critical challenges that authors have examined, coming towards the final evaluation

of the status of People Analytics in research and identifying the potential area that required more research from our perspective and would be the subject of further research.

3.7 Publication and Research Areas Analysis

3.7.1 Publication Types Review and Journals Analysis

As this literature review focuses on the new research field, we have also included more comprehensive books and book chapters on the scope of this PA review. During the extensive search for the relevant literature through google scholar and multiple databases, we identified 85 journals, 36 conference papers/proceedings, 23 book chapters, and five complex books focused on the PA agenda (see Fig. 13).

By reviewing the year of publications we can see that conference papers and proceedings have been starting point of the people analytics research (Fig. 14).

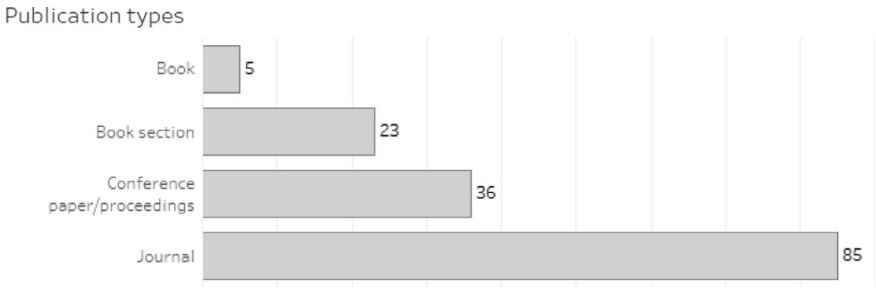

Fig. 13 Publication types distribution

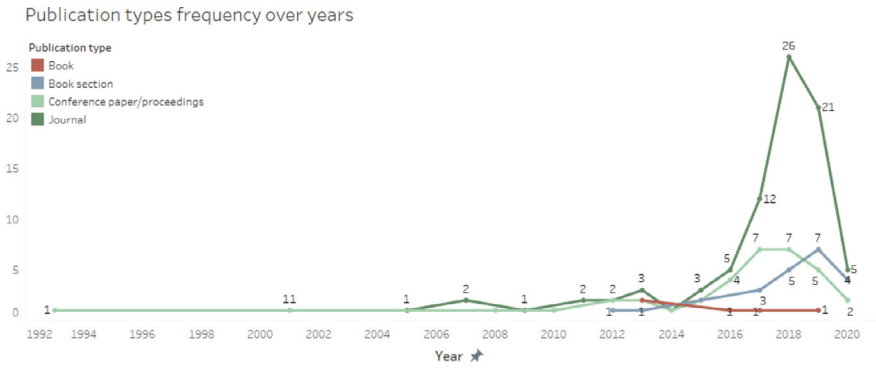

Fig. 14 Publication types frequencies over time

From the perspective of methodologies used in the particular types, empirical, non-empirical and hybrid have been used in all of them (Fig. 15). The highest proportion of empirical publications were of type conference papers, where 26/36 have been purely empirical and 4/36 hybrid. Most journal publications have used empirical methodology, more in combination with non-empirical, than pure empirical. The book chapters had a majority of purely non-empirical methodologies, and by reviewing books, 80% of them were identified as hybrid methodologies.

As a next step, we have decided to look closer at particular journals and published PA papers. Over half appeared in the unique journal; 13 journals have been identified to contain more than one PA-relevant research paper (Fig. 16).

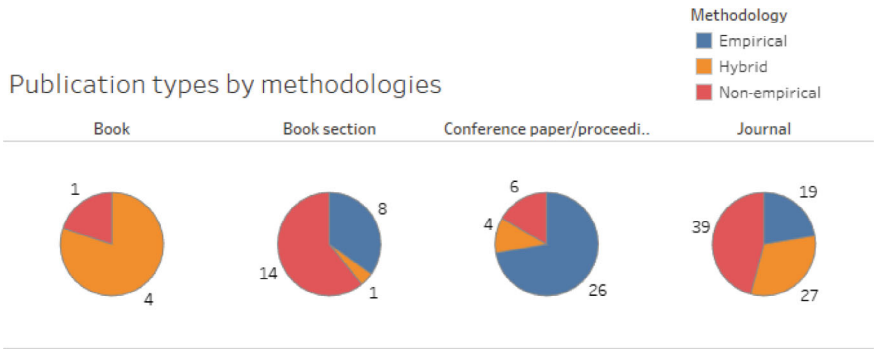

Fig. 15 Methodologies used by different publication types

Top 13 Publications by frequency

Publication name	Frequency
Strategic HR Review	15
Journal of Organizational Effectiveness: People and Performance	6
Human Resource Management	5
International Journal of Trend in Scientific Research and Development	3
The International Journal of Human Resource Management	3
Employee Relations	2
European Journal of Operational Research	2
HRM 4.0 For Human-Centered Organizations	2
Human Resource Management International Digest	2
Human Resource Management Journal	2
International Advance Computing Conference	2
International Journal of Recent Technology and Engineering	2
Management Research Review	2

Fig. 16 Top 13 most frequent publications (journals and books) identified in PA review

Fig. 17 Wordcloud of journals and books where reviewed articles and book chapters were issued

In the last stage, we aimed to identify the notion of the journals. After removing the common words from the journal titles (such as prepositions, or "journal", "conference", "research", "review"), we have created a word cloud of a maximum of 100 most frequent words appearing in the titles, displayed in Fig. 17.

The most dominant from the business/non-technical world have been identified words Management, Human, Resource, HR, Strategic and more. We can also see the more IT and analytics–related words, Information, Data, Engineering, Analytics, Technology, Science. Proportionally we might conclude that most frequently, this topic is published in HR and Management-related journals.

3.7.2 Research Area

In this literature review have been created research areas based on the iterative approach. After examining the aim of each study, challenge or problem identified, and its output, we tried to identify the key topic area/field.

The following information needs to be pointed out before looking at the final categories displayed in Fig. 18. At first, we kept only one main focus area for each study. In the case of complex publications and books, where have been paid equal attention to multiple areas, we have used the general category. The second point is that research areas might be influencing each other. Deployed models and solutions invented and applied to a specific problem in a particular research area might also apply to other research areas. An interesting illustrative example for the second observation is CV analysis. CV analysis might be a helpful tool for improvement of the candidate selection for the open positions (recruiting area). Having matching candidates in their positions might positively impact not only the recruitment area [113] but also will bring new talents in the company and job matching [62] vs. employees currently being in the position might also be one of the aspects impacting employee retention (current employee position fit as an attribute in the model to

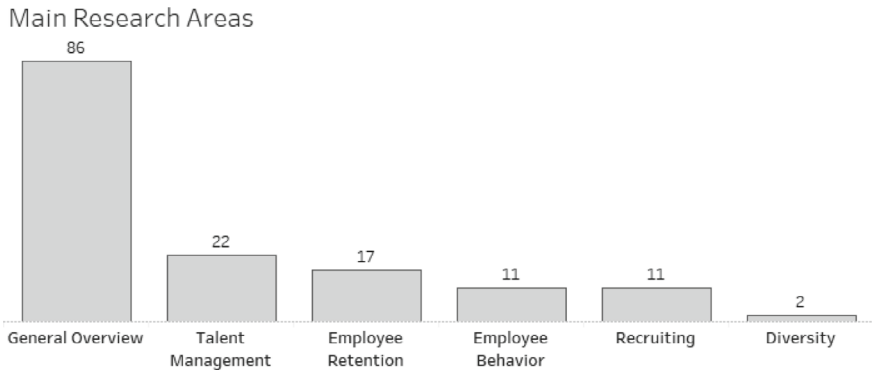

Fig. 18 Research areas under the umbrella of people analytics services

identify employee turnover). The content of CVs might also be estimated gender, age, country of origin of the candidates, which is one of the relevant topics for diversity. Lastly, examining patterns in, e.g., the loyalty of employees in the company by screening employee CVs might be an interesting case study in employee behavior. Therefore, we have decided to cluster the studies based on their focus area, including the context where the findings were proposed to be applied. The frequency of specific areas is visible in Fig. 18.

To consider the different approaches identified in the publication, we have focused on examining the approach versus research area (Fig. 19). This examination might be helpful to identify an approach for further research within a specific topic area.

In the General (and complex) topics, we could see the dominant non-empirical research. In other areas is dominant empirical research. As this category is the most frequent, this share impacts the overall split of methodological approaches used (Fig. 10). All publications related to Employee retention or support of recruiting services used an empirical approach. This situation might cause the fact that these research areas are more towards concrete topics or problems where people analytics services might help human resources, and the general theory of recruiting and retention from an HR perspective is not in the scope of this article. However, the "domain knowledge" when running empirical research and defining the research problem might be necessary. In the diversity topic, both research areas were identified as a hybrid to be considered balanced; however, looking at a low number of publications, we can already conclude there is the potential for further research.

In the end, a deep dive into the subtopics within the research areas are available in Fig. 20. This review provides the detail about the challenge on which author focused.

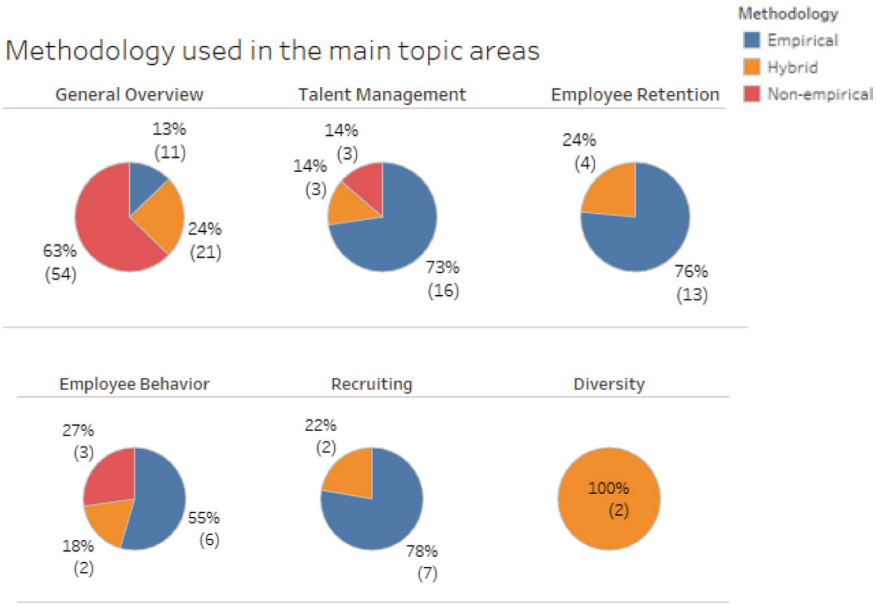

Fig. 19 Research areas versus methodologies applied in reviewed publications

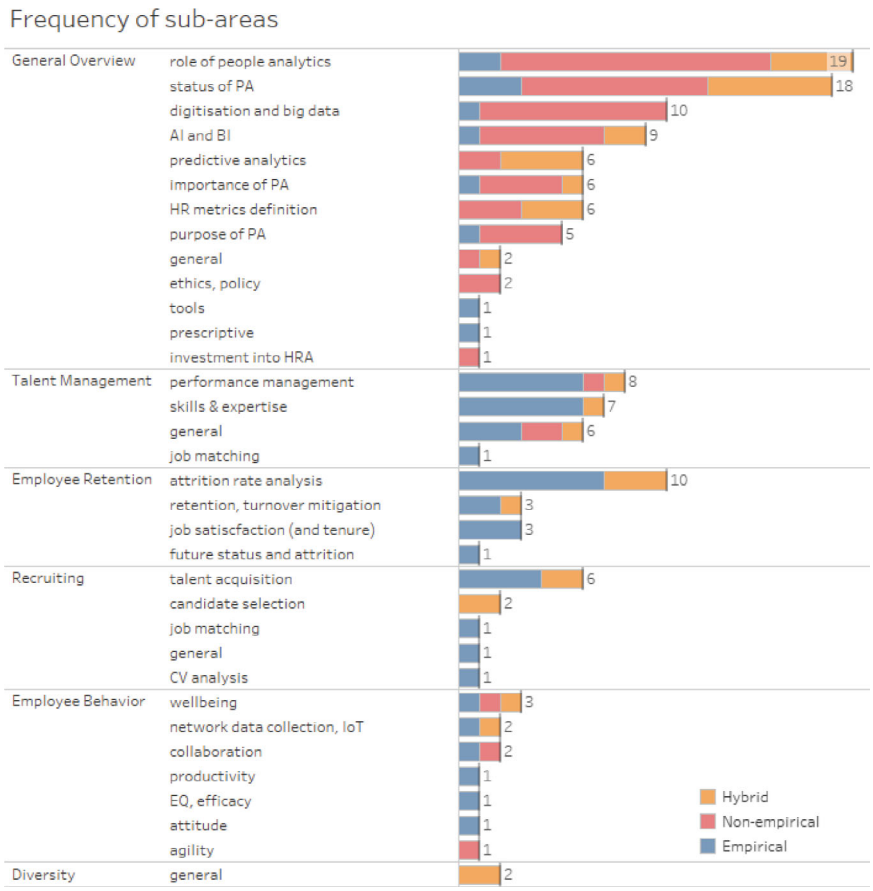

Fig. 20 Frequencies of detailed topics within main research areas and examination of methodological approaches used

4 Conclusion

This literature analysis aims to examine the status of People Analytics and its position in the scientific area. Based on the frequency of publications over time, we can conclude that this topic has become very popular in recent years. This "boom" might be interlinked with the digitalization of the workplace and evidence about employees, which leads to increased data available for workforce analysis.

Literature was collected from various databases (e.g., SpringerLink, Web of Knowledge (Publons), JSTOR, etc.) based on the PA relevant keywords. Additionally, we have included cross-referred publications in case we have identified them as necessary for our research. The publications were reviewed, and their relevance for this literature review was assessed. Till the first half of 2020, have been collected

149 relevant publications, whereas 117 of them, 79%, were published over the last five years.

Like Scholz [123], multiple authors evaluated the current coverage of PA in scientific literature as insufficient and concluded that more research is needed. In addition, the modern technological environments, the Internet of Things, and data from communication platforms play a role in many domains and require attention in this field. The titles' frequent words HR, human, data, analytics, and people (Fig. 9) signalize the intersection of HR and data analytics domain. In addition, attrition, retention, talent and performance appeared in the word cloud, and they are present within research areas in 3.7.2.

An interesting observation is coming towards the methodologies used in the reviewed publications. Based on the detailed review, 36% of publications used empirical and 40% non-empirical methodology. An additional 24% of publications have been evaluated as a hybrid using both empirical and non-empirical methodologies. Within empirical approaches have been most frequently used case study and experimental approaches. Publications using empirical methodologies introduced new concepts, applied predictive analytics [109] and machine learning, and discussed specific cases. In non-empirical studies have been by conceptual analysis and systematical literature review deepened and extended the understanding of People analytics services, their purpose and role in the companies.

Looking for the first decade of publications, a decent share of non-empirical research has been conducted focusing on the role of people analytics, its purpose, operating model. The conceptual research identified that using predictive analytics, the impact of digitalization and an increase of big data had been affecting HR management and be frequently considered a challenge.

From the research area analysis, we have identified a lower number of publications in recruitment and diversity. Therefore, we would like to include workforce diversity in the context of recruitment in the practical part of this literature review. On the contrary, there are multiple empirical publications about the retention of employees, their churn and attrition. The authors used various models and applied different statistical methods. Assessment of different models and their qualities and proposal of a new solution are the ambitions for the stage of this review. Various complex publications were identified, but also very detailed oriented on specific business problems to solve. The concrete case studies and topics might be the reactions to the identified business challenges PA services face in practice.

Increasing demand was identified in the field of behavioral analysis and qualitative workplace. Additionally, the Covid-19 crisis has significantly changed working conditions and consequently also employees' behavior. Based on [24], productivity, wellbeing, ways of working, gender pay gap, and other HR cases are relevant challenges for 2021. That can be translated into a need for PA services in the field of employee behavior. Respecting employees' privacy and using data carefully is a key to ensuring that the employer would not be perceived as "a big brother". The topic of employee behavior is so robust. It connects different aspects that need to be studied that we see the continuous ambition to focus on this field in the future.

Prior literature review revealed additional topics connected with People Analytics from the operational perspective as other domains that collect, use data, and work in the digital environment. Namely, data security and data privacy, company and tools policies implications, and data quality management impact the availability of employee-related data and require additional attention based on multiple conceptual studies. HR Information systems, robotic process automation appmight also be connected to People Analytics services. Very complex and interdisciplinary problematics of Strategic People Planning might also be considered in the scope of People Analytics, but heavily involve also financial aspect, process management a people strategy. These topics were not in scope as we believe they might be objectives of standalone research.

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Analysis of the Most Common Mass Communication Tools of Marketing Communication Respecting the Criteria of Sustainability Within Tourism Industry

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Abstract The paper explores the effective utilization of mass communication tools in marketing strategies is paramount. However, in light of increasing environmental concerns and social responsibility, the concept of sustainability has become central to modern business practices. This paper seeks to analyze the intersection between mass communication tools and sustainability criteria within the context of the tourism industry. Through a comprehensive literature review, this study identifies the most common mass communication tools employed in marketing within the tourism sector. Furthermore, it explores the evolving landscape of sustainability criteria and its integration into marketing communication strategies.

Keywords Tourism industry · Cultural tourism · Sustainability · Marketing communication · Tools of marketing communication

1 Introduction

Tourism has a huge potential for development, and it is an important source of national income, and an increase in foreign exchange earnings which affects other sectors of the economy. On the other hand, tourism is a fragile sector of the economy, hardly impacted by threats (e. g. COVID-19 pandemic) from the macro marketing environment. This fault can be compared with the 1990s international tourism volume and rehabilitation of economy, so it may take several years in case of sustainable

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progress [44]. COVID-19 pandemic taught the tourism industry, politicians, visitors, stakeholders, and even researchers, but at the same time, opportunities on the way to the changes. In this new/changed context, one of the challenges facing cultural tourism is to turn the crisis into an opportunity and accelerate tourism transformation sustainability. As Fletcher [21] affirmed, even after the COVID-19 pandemic, the world cannot afford to rehabilitate past achievements. Excessive mass tourism affects the environment (including e. g. pollution and resource depletion) due to the unsustainable tourism. Despite the uncertainties that the health and economic crisis has induced in the tourism industry, one of the essentials consequences has been the consolidation of local tourism, especially domestic tourism [30].

2 Materials and Methods

Drawing upon theoretical frameworks and empirical evidence, this research aims to evaluate the extent to which mass communication tools align with sustainability principles in the tourism industry. By examining various best practices, the paper provides insights into the challenges and opportunities faced by businesses in integrating sustainability into their marketing communication strategies. Ultimately, this analysis contributes to a deeper understanding of the relationship between mass communication tools, sustainability, and marketing within the tourism industry. The findings offer valuable implications for practitioners, policymakers, and researchers seeking to foster sustainable practices in the realm of tourism marketing communication.

The aim of this paper is therefore to investigate and analyze the utilization of mass communication tools in marketing strategies within the tourism industry, with a particular emphasis on how these strategies align with sustainability criteria. By examining the current landscape of marketing communication practices and sustainability principles, the study seeks to identify opportunities for integrating sustainability into mass communication efforts within the tourism sector. Ultimately, the aim is to provide insights and recommendations that can guide businesses, policymakers, and researchers in promoting more sustainable marketing practices in the context of tourism.

3 Results and Discussion

Sustainability refers to the improving quality of life while living within the carrying capacity of supporting ecosystems. Sustainable tourism is extensively used as a panacea in the tourism discourse; however, there are still many challenges in its communication, understanding and efficient implementation. The work presented here aims to contribute to those issues by presenting the concept of greening tourism. Greening tourism is a response to the questions of competitiveness and ecological sustainability of tourism, but also the policies of United Nations and European Union

[16]. Moreover, they referred to the development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Economic, social, cultural, natural, and environmental utilization for the current generation without compromising future generation have become core goal of the tourism industry to achieve sustainability [20]. Regarding the tourism sphere, it considers the needs of the tourists, tourism companies and host communities. Nevertheless, the contribution to spreading the idea of sustainability is part and parcel of the Sustainable Development Goals (SDG) identified in 2012 at the United Nations Conference in Rio de Jaineiro based on three pillars (economic, social, and ecologic). After, they replaced them with the Milleniun Development Goals adopted in 2000.

In the framework of SDG and regarding tourism, following goals (no. 8., 12. and 14.) are the most related to tourism development, such as sustainable consumption and production, decent work and using natural resources responsibly. By establishing sustainable development principles, organizations engaged in tourism and even the whole of society can open new opportunities for growth and lower their risks to implement a well-functional society, a healthy environment, and a stable community. Tourism sector is relevant to each of the following goals of sustainable development:

1. tourism is opportunity for creation of new job places for local community which raise their income—sustainable (urban) tourism with emphasis on positive relation between environment, human and community cause in increasing long term effect on resident quality of life, some of these effects are increasing incomes, recreation of service facilities, improving urban decoration with cultural symbols, increasing job opportunities [41],
2. Tourism is accelerator of agricultural products with its high demand,
3. Tourism tax can be a good source of reinvestment for healthcare system,
4. Tourism sector can provide youth, women, and special needs people with decent job through quality education—there is a mismatch between training and the labour market in sustainable tourism, which generates a training need [5],
5. Tourism provides with opportunity to get job places for women,
6. Tourism is one of the leading sectors with high requirements of clean water and sanitation,
7. As the huge energy consumer, tourism promotes investment towards green and ecofriendly energy—Protected environment and preserved cultural heritage and natural assets through the reduced usage of energy and reduced hazardous pollutants will consequently lead to economically, socially, and environmentally sustainable tourism sector [25],
8. Tourism is considered as one of the export shareholders—cooperation in tourism is considered crucial for sustainable destination promotion, addressing several opportunities to decrease the level of competition among actors to achieve advantages for all [24],
9. Tourism development depends on good conditions of infrastructure and innovation—he main directions of using innovative marketing technologies in the field of tourism services are considered: release of new types of tourism product,

change in the organization of production and consumption, identification, and use of new markets, as well as the use of new equipment and technology [7],
10. By involving all local community and stakeholders, tourism can support development of their origin places, even rural and remote places—the key directions in the management of innovation development of entrepreneurship in tourism were characterized based on the assertion of the need to promote successful innovations in tourism and the entrepreneurial ecosystem through the stakeholders' interaction [6],
11. Tourism has direct relevance to preservation cultural and natural heritage, improving site infrastructure and investment to green transport means,
12. Tourism sector requires sustainable consumption and production system for which enhance community wellbeing overall—due to the nature of the cultural tourism product, which is created at almost the same time it is consumed, during a tourist experience, the development of a new tourism product must be considered not only a controlled process, but also as a cultural synthesis which allows us to transmit knowledge about the specific culture and tourism market and to understand how to keep pace with cultural and ideological changes [22],
13. Tourism stakeholders ought to play essential role in climate change preservation and carbon footprint reducing process,
14. Coastal tourism usually depends on good marine ecosystem,
15. Colorful biodiversity is the main source of tourists visit purpose,
16. As tourism involves multicultural integration it enhances tolerance and undestanding among them,
17. As tourism includes several sectors of economy, it involves new stakeholders and fosters public and private partnership.

However, tourism is considered as a huge potential source of profit, it causes serious problems such as overcrowding, cultural appropriation, and the loss of authenticity among others [28]. Tourism brings money and jobs to cities and regions, but it also can also damage residents' everyday lives, as well as the area's culture and heritage. Under this scenario, sustainable tourism development at cultural sites offers a new perspective, as it places cultural heritage and local communities at the centre of decision-making processes. That means it involves local communities and other stakeholders in the decision-making processes as a key to ensuring the benefit of both cultural heritage and the local population. There is currently a growing concern about the consequences of tourism activity on the environment. In this regards, sustainable management is understood as a key element that can help destination marketing organizations (DMOs) to improve a tourist destination's competitiveness [1]. The objective of sustainable cultural tourism is to ensure good conservation practices along with authentic interpretation that supports the local economy. Tourists' travel decisions can be influenced by appropriate policies that seek to encourage them to choose travel plans leading to more sustainable tourism practices [4].

The Role of Communication in Sustainable Development

In the context of sustainable tourism development, communication appears as a strong way for integrating stakeholders (private and government sectors) and the local community [17]. Principles for the implementation of efficient communication must be filled by the integration of idea of sustainability anywhere like not just as a goal but as an ongoing process and clear and understandable communication (explanation through storytelling) showing different channels (ads or websites) of tourist companies and being a vehicle for knowing all SDG. It is crucial to consider that sustainability is not just environmental and climate protection, but it is social and economic issues to avoid stereotypes and to provide a comprehensive view of the progress made and prospects in the relationship between communicational tools and sustainable tourism. Tourism activity at this destination belongs to the service sector and is customer-oriented, therefore, the effectiveness of communications that provide a link between the government, the producer of tourism services (tour operator) and the consumer (tourist) is crucial.

Even though each SDG can be promoted by this way of communicating each has its management and communication is an unreplaceable part of it. For example, online financial services, call centers for poor families, online registration systems, education based on new communication technologies, new jobs for all genders and ages through ICT, saving water and energy according to the forecast of ICT, and access to renewable energy, acquiring the job of future with digital skills, easy access to information for business, strongly connected cities and communities, digitalization of forecasting of extreme climate changes, GPS and satellite tracking, open access services, co-operating among participants. Some of institutional information providers provided practical information of big company CEO claiming that the main issue of sustainable development on 4 Cs elements: collaboration, controlling, communication and commitment highlighting practical value of communication and collaboration for total development.

Communication is not just a common process of information transition. Sustainable tourism communication begins from the visitors travel decision to side and lasts their return to home [43]. Integrated marketing communications consistency for sustainability significantly influences guests' ecological knowledge and brand equity, which, in turn, considerably impacts guests' satisfaction [10]. Furthermore, communication need to be tool of strategic planning at the same time, due to lack of it can lead the failure. Sustainability has become an important strategic objective for tourism destinations worldwide. All analytical tourism competitiveness models make direct or indirect positive references to sustainability. It is accepted that sustainable tourism can reduce resource costs and help create market differentiation [38]. According to Bramwell and Lane [12] communication also includes "how people use message to generate meanings within and across various contexts, cultures, channels, and media". Additionally, other communicational matters pinouts the lack of strategic communication applied to destinations [39]. To solve this problem a strategic communicational plan is mandatory to define principles, goals, contents and means not only to create content but to manage communication.

Regarding to the history of communication for development, there are three development paradigms: modernization, dependency, and participation [28]. While in the middle of the twentieth century modernization generally used one-way media communication, on top-down bases in order to disseminate developed countries examples for implementation in undeveloped ones belongs to the model sender—message—receiver [34], in the 70's there was formed dependency theory [40] as a consequence which included additionally two-ways communication also and was useful to achieve autonomy. Few years (respectively decades in the less developed economies) most development agencies and organizations consider the essence of the participatory paradigm to focus on human perceptions, opinions, and beliefs in the decision-making process and based on just two-ways communication belonging to the decision maker a dialogue decision-maker B model [3]. The beneficial features of this method depend on communication that empowers people, focused on dialogues and listening is essential such as talking [23]. Communication should be based on not just coding and message exchanging but also should be problem-posing [9], moreover research [3] and planning tools [33], and a solemn stage in the development decision-making process. The base role of communication on strategic planning includes following functions [45]: institutional positioning, campaign-based fundraising, and reaction of indigenous community in conflict situations. Andelman [2], a proposed communication model ranging from simple information provision by involvement participants encouraging their opportunities for decision-making. This process includes informing to raise awareness and enhance influence and involvement [28] through knowledge and public support respectively (Fig. 1).

Gorlevskaya [27] explains this process by the side of tourist decision making, the first step is Awareness created by mass media, and there is essential role of PR activities and Blichfeldt [8] also highlights tourists' storytelling mean as the most efficient strategic communication tool, because of its high rate of trust. The second step is needs or consideration were targeting audience starts looking for information, where consumers get information through web sites and social media or mobile marketing and is ready to make decision: their choice which is the last step of the process (Fig. 2).

Sustainable tourism development (STD) conducts tourism ecosystem which contains several tourism system elements [31]. STD generally considered as the relation to tourist destinations and further encouraged to hospitality management.

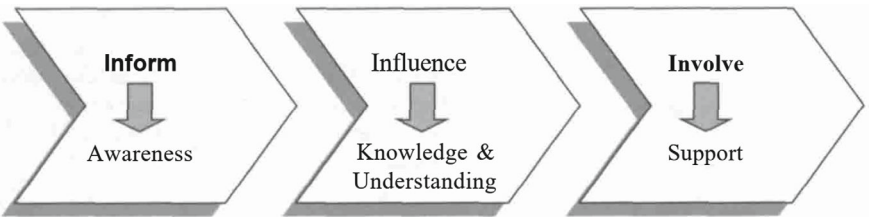

Fig. 1 The "3Is" of communication—a continuum to build support [28]

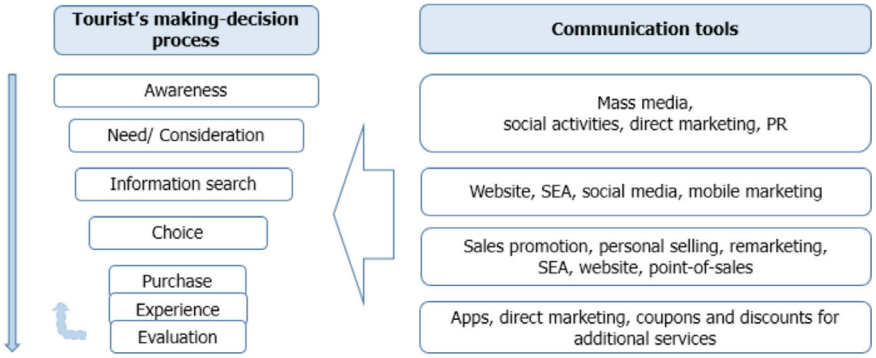

Fig. 2 Making-decision process and communication tools in tourism [27]

Hence, it is often viewed as encompassing a triangular communication (Fig. 3) among tourists' host areas, and the tourism industry [15].

Bramwell and Lane [12] highlighted that, tourism businesses often have few reasons to want to promote sustainable tourism. Major industries actions aim to accomplish clear competitive advantages and/or improve results and considering that entrepreneurs should follow a holistic strategy and include all stakeholders on all levels form micro to macro [18].

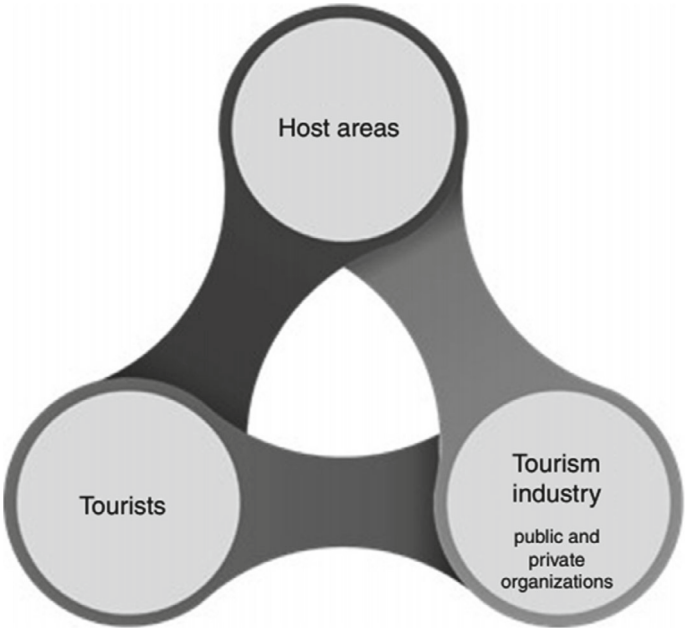

Fig. 3 Sustainable tourism ecosystem [15]

The recent studies focused on participation of local community on tourism activities [14, 35], and balance among the triple bottom-line dimensions demand an intensive level of collobation among nonprofit organizations, businesses, citizens, and governments. Strategic communication [37] is considered as prerequisite and it is an efficient way of decision-making tool where public participation is priceless, it consists of all policy making process: from formatting of vision to implementation and monitoring of plans. Benefit from strategic communication can be seen on the followings: strengthen capacity building, encouraging people work together, motivation, raise awareness, accelerate, and improve people behavior, empower local people for appreciation their cultural values and encourage efforts into the future. Mazza [32] described practical strategic communication on the following stages of communication process:

1. awareness raising,
2. information,
3. education,
4. relations encouragement,
5. experience encouragement,
6. action encouragement.

For analyzing strategic communication Blichfeldt [8] suggested two groups of methods:

1. According to transmission model:
   - narrative analysis: impact of storytelling,
   - rhetorical analysis: study of language: source, emotion, and logic,
   - semiotic analysis: sign within society,
   - discourse analysis: text meaning exploring—induction (usually for on-line means).
2. According to interaction model:
   - content analysis: identification presence of concepts or words in online means,
   - netnography: online community and cultures research focusing consumer behavior and attitude.

Furthermore Blichfeldt [8] marked the role of challenges in sustainable strategic communications in tourism such as: greenspeak (saying and doing), greenwashing (more saying than doing), and greenhushing (pretending as sustainably focused by disinformation) issues on the communication process, comparing their intent, goals and impact to development of sustainable tourism.

Stakeholder in tourism industry is divided into generally four main groups [26]: tourists (visitors), residents (local community), entrepreneurs, and government. Jamal and Getz [29] had expanded version of this division including public organization, tourism industry associations, regional authorities, community groups, civil societies and agencies and special interest groups. CAAP (Communication awareness action planning) system offers communication system attenders dividing into two main categories: plan facilitators and target groups (Fig. 4).

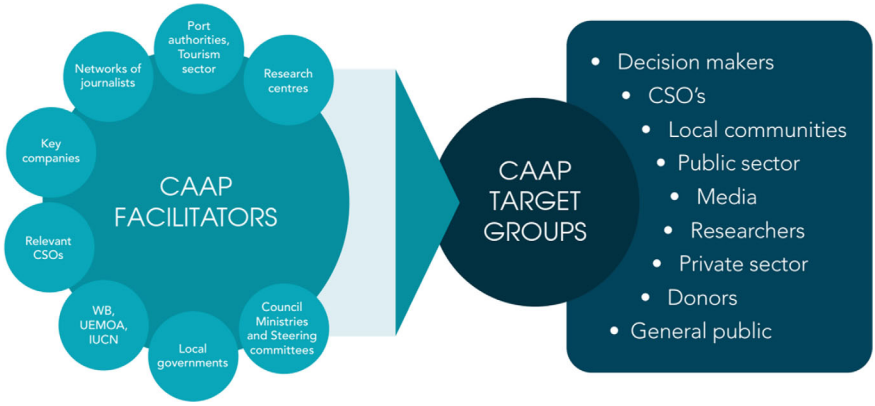

Fig. 4 CAAP main facilitators and targeted audiences [36]

The main principles of strategic communication may be briefly explained as: engaging stakeholders and opinion leaders, cooperation, enhancement of organizational management and communicational skills, positive word of mouth and reputation, an implementation by permanent monitoring and evaluation.

To enhance effectiveness of strategic communication there are proposed following principles:

- Diversification of interpretation and application. Communication process involves tremendous types of participants and there is no universal method of commination. Furthermore, each time there is several purposes and goals of communication with participants.
- Integration into management planning. Communication should not be the part for just dissemination of results, it must be indivisible part of management planning [33] instead must exist in each stage of management. The main gap between management plan and success in communication research [19] and it may be guarantee for achievement of expected goals.
- Moving from communication objective to means and actions. After figuring out concepts and ideas, it should bring along participatory action [45] regarding integration with all communicators. There may be used one-way media and more powerful for changes two-way communication means.
- Permanent monitoring and evaluation. These two actions must be followed on each stage of communication process. Clearly assessment is fundamental step for management [42], and adequate e indicators of evaluation may provide projects with appropriate direction.
- Professionalizing and systematically mainstreaming communication process in future. Building capacity and upgrading communication system in future is requirement of present conditions, there will be every time fresh challenges which demand for innovative approach [13].

Although it is now typical for marketing communications to be able to contribute to social and environmental harms, it is important to highlight that marketing communications tools can be used in efforts to achieve a variety of sustainability goals. Within sustainability marketing, the attributes of social marketing are often emphasized, with national governments and NGOs quite often using marketing communication tools to build awareness of issues at the heart of sustainability (e.g. climate change), for example. In the concept of sustainable marketing management, marketing communication is as important an element of the marketing mix as in the traditional marketing management concept. Indeed, without effective marketing communication it is difficult to build awareness of the sustainable solutions that organizations offer to customers. Effective marketing communication creates long-term relationships with customers (which are further strengthened at different stages of the product life cycle). The challenge for marketing managers who manage an organization's communication strategy in line with the concept of sustainable marketing management is to ensure that marketing communication campaigns respect the nature of customers and use the power of different marketing communication tools in such a way that they are not associated with negative social and environmental aspects of communication.

Sustainable marketing communication represents a significant step in the evolution of marketing communication.

- traditional marketing communication focused on promoting the product towards the customer,
- marketing communication in the concept of relationship marketing focuses much more on communication with the customer, as well as on acquiring customer information to serve them more effectively,
- sustainable marketing communication highlights the organization more than the product offering, thus allowing customers to learn information about the organization, but above all enabling a dialogue between the organization and the customer.

This dialogue creates a dual focal point for sustainable communication strategies:

- communicating with customers about the sustainable solutions the organization offers through its products,
- communicating with customers but also other stakeholders about the organization.

An organization's efforts to promote the sustainable solutions offered by their products must be carefully planned, managed, and controlled from a marketing communications perspective. The starting point of a communication strategy is the setting of marketing communication objectives. Each individual communication activity has a set objective (for example, from the simplest in the form of a response to a customer request to building awareness of the product in a specific customer segment).

The most common objectives of marketing communication include the following:

- Creating awareness. No matter how exceptional a tourism product, i.e. location, destination, brand etc., it will struggle to survive in today's rapidly evolving and changing markets without customer awareness. One of the key factors preventing the development of sustainable tourism, as well as their transfer from niche to mass markets, is very often the lack of widespread awareness among customers (which in turn suits established competitors with traditional tourism product).
- Communication. The dissemination of information towards customers concerns products and their availability, the nature of the tourism organization and its activities. Efforts to develop a sustainable marketing management approach include informing customers about sustainable issues (often in general terms) and their relationship to lifestyle and the choices available to customers. However, it should be noted that the provision of information alone is very rarely a sufficient motivating factor for customers to adopt sustainable consumption behavior or consumption.
- Reminder. One of the objectives of marketing communication tools may be to remind people of tourism products and their availability or the need to maintain or replace a traditional tourism product. Marketing managers can play an important role in the sustainable use of products by reminding customers of the need for standard product consumption, thereby creating opportunities for product added services.
- Persuasion. Customers often need to be persuaded to try a new product, change brand loyalty, or change consumer behavior in a (positive) direction.
- Reassurance. This involves reassuring customers by confronting direct or implied criticism of products (e.g. also using competitors' marketing communications) and reassuring customers that buying the organization's (sustainable) product was a rational decision.
- Motivation. The aim of marketing communication can be to motivate customers to react in a certain way, for example, through a direct response in the form of a phone call, a click on a website to a specific product (offer).
- Remuneration. By rewarding we mean rewarding customers through direct benefits for previous loyalty and loyalty as well as other (active) behaviors. Many organizations both incentivize and reward customers.
- Building collaboration. Collaboration with customers should be created through relationship-building activities as well as through interactive communication (e.g. interactive websites).

Marketing communication offers quite a wide range of tools to be used in the processes of achieving the above objectives. From the point of view of the traditional marketing management concept, marketing communication tools were divided into above-the-line and below-the-line in terms of effort and budget. However, in recent years this "magic" line has become blurred, gradually losing its meaning, and therefore many marketing communication organizations and agencies have started to talk about integrated marketing communication.

In terms of the use of marketing communication tools in the concept of sustainable marketing management, the same tools can be discussed as in the traditional concept, but the implications and impacts of each tool in terms of sustainability are different.

Advertising

Advertising is the marketing communication tool with which the public most often associates marketing. Advertising uses mass communication channels such as television, radio and print media. Advertising is an influential marketing communication tool that can reach a large or dispersed part of the market, very often repeatedly, with a persuasive and informative content of the marketing communication message. Advertising has several limiting factors, such as the unidirectional delivery of the message content to the entire audience.

In terms of promoting sustainable marketing strategies, advertising is used quite often for certain product categories (e.g. cars, cleaning products). Advertisements often use vague, unspecific, unsubstantiated, and misleading claims, as well as claims that contain so-called moral appeals.

There are several challenges that marketing managers face in using mass advertising in the process of promoting sustainable products more effectively. Advertising has very strong associations with the traditional marketing paradigm, which emphasizes the demand side and focuses on the (often superficial and shallow) design and style of products rather than their true meaning and relevance. For this reason, many marketing managers (as well as customers) distrust advertising as a marketing communication tool and therefore do not want to use it in promoting sustainable, credible product attributes. However, it can be a challenge to communicate meaningfully through advertising about the complex, interplay of the social, environmental, economic, technical and customer benefits of a product from a sustainable perspective using, for example, a 30-s TV advert or a single A4 advert in a magazine.

Public Relations as solution for Strategic P Communication.

Communication can be divided in several groups and forms, while each one has its unique features. Interpersonal communication has more feelings, correct message, and content, through this type of communication communicators can reach to joint solution for issue. As the disseminating methods, there are used several types of communication such as personal communication, mass media, education, advocacy, and public relation. When personal communication and advocacy involves more meeting for small community and mass media covers more audience for an exact time, education provides communicator trainers for a long time, public relation may effectively involve key actors for awareness raising campaign as a chartered institution of PR in the UK (2006) defines it like that "Public relation is the discipline which looks after reputation, with the aim of earning understanding and support and influencing opinion behavior. It is the planned and sustained effort to establish and maintain goodwill and mutual understanding between an organization and its public."

PR is vital to the success of tourism business, due to its function of creation awareness of special destinations, attraction, or event. It let the tourism industry encourage their profile within local community and target markets. The main reason of using PR

for whole tourism system is building positive relationships which generates interest to the destination. Major of tourism firms rely on word-of-mouth advertising, which is built through effective PR campaigns. PR professionals can help destination to create reputation through positive image publication, advertising, and events. PR for tourism sphere contains promotional events such as sport events, festivals, and cultural events. PR can be used for marketing, advertisement, or promotional purposes, moreover it is good tools for crises management to fight negative events impacting travel plans. PR is all about perception, thus positive imaginary attracts flow of visitors while bad one may be reason of avoiding the destination.

Strategic communication for sustainable tourism requires more integration between the public, and private sectors and visitors. There is a gap between the public sector and private sectors in SDG communication which carries out serious consequences as the low rate of awareness. So that the purpose of this research is to explore communication tools and strategies and design an efficient methodology for communicating sustainability to enhance cultural tourism in the Bukhara region by the assignation of responsibility and duties to the tourism system participants.

Based on the above mentioned, the research aims to study the ways of communicating and promoting national brands and their impact on tourist incoming in cultural tourism destinations. Furthermore, to develop sustainable tourism by enhancing cultural tourism in the regions.

Online Marketing Communication

The Internet and other modern information and communication technologies have created a "revolution" in marketing communication. In the early days of online marketing communication, most organizations transformed their marketing communication tools (e.g. television and print advertisements) into websites, making them a source of information for customers. Such use of online marketing communication is characterized by the one-way provision of information to customers and therefore cannot be considered as a tool used in relationship-building processes.

With the development of various forms of online marketing (e.g. social media, blogs, product review sites), a space has been created for initiating and sharing conversations about products, brands, and organizations, and thus building relationships with customers. In terms of online marketing, the trend for many organizations is to create stand-alone websites to educate customers about sustainable aspects related to the brand.

4 Conclusion

Strategic communication for sustainable tourism requires more integration between the public, and private sectors and visitors. There is a gap between the public sector and private sectors in the area of Sustainable Development Goals communication which carries out serious consequences as the low rate of awareness. So that the purpose of this research is to explore communication tools and strategies

and design an efficient methodology for communicating sustainability in order to enhance cultural tourism in the any region by the assignation of responsibility and duties to the tourism system participants.

Based on the above mentioned, the research aims to study the ways of communicating and promoting national brands and their impact on tourist incoming in cultural tourism destinations. Furthermore, to develop sustainable tourism by enhancing cultural tourism in the regions.

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Computer-Based Linguistic Content Analysis to Discover the Emotional Impact of Military Euphemisms

Solomiia Fedushko, Zoriana Kunch, and Liliia Kharchuk

Abstract The use and linguistic analysis of military and political euphemisms in web communication play a crucial role in understanding the complexities of discourse surrounding armed conflicts and political events. This study shows that using computer-based content analysis to study web content about the Russian-Ukrainian war offers researchers a powerful and efficient means of uncovering patterns, sentiments, and narratives in the digital sphere. Thisodology uses natural language processing and machine learning techniques to identify and classify the sentiment or emotion expressed in the text, whether positive, negative, or neutral. The findings emphasize the importance of understanding the socio-political context in which these expressions emerge. The study reveals the strategies behind eu-me language and its impact on public discourse, providing a foundation for future research to explore the ethical implications of language manipulation and the role of digital communication in shaping contemporary conflicts.

Keywords Euphemisms · Discourse · Russian-Ukrainian war · Web content analysis · Sentiment analysis · Military and political language · Digital propaganda · Online communication · Linguistics

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1 Introduction

Linguistic and statistical analysis, as powerful tools, play a crucial role in understanding public opinion and media coverage. These analytical approaches harness computational methods to extract, analyze, and interpret large volumes of online textual data, offering researchers insights into the narratives [1, 2], sentiments [3, 4], and trends prevalent in digital discourse [5, 6]. The significance of these approaches cannot be overstated, as they provide a deep understanding of the public's views and the media's portrayal of events.

Web content [7–9], such as news articles, social media posts [10, 11], blogs [12], and online forums [13, 14], is a rich source of information for understanding public opinion, media coverage, and the overall discourse surrounding the Russian-Ukrainian war [15–17]. Researchers can identify key themes, topics, and patterns by systematically analyzing and categorizing textual data using computer-based content analysis techniques [18]. This process involves various computational methods, including natural language processing [19], machine learning [20–22], and sentiment analysis [23–25]. One of the critical advantages of computer-based content analysis is its remarkable efficiency in handling vast amounts of data. Traditional manual content analysis methods would be laborious and resource-intensive when applied to the extensive and constantly evolving digital landscape. However, by employing automated techniques, researchers can process large datasets, capture real-time updates, and identify emerging trends promptly, providing a sense of reassurance about the practicality and convenience of this approach.

The computer-based content analysis of web content about the Russian-Ukrainian war offers researchers a powerful and efficient means of uncovering patterns, sentiments, and narratives in the digital sphere. This analytical approach empowers scholars, policymakers, and stakeholders to gain comprehensive insights into the dynamics of the conflict, contributing to a more nuanced understanding and facilitating informed decision-making.

2 Related Works

Researchers employ several methodologies for analyzing web content to gain insights and understanding from the vast online information. Here are some of the main methodologies:

- Content analysis systematically examines and categorizes textual, visual, or audiovisual content [26, 27]. Researchers define coding categories and analyze the content based on predetermined criteria. This methodology allows for quantitative and qualitative web content analysis, helping identify patterns, themes, and trends across different sources.

- Sentiment analysis [3, 4], or opinion mining, focuses on extracting and analyzing the subjective information in web content. This methodology utilizes natural language processing and machine learning techniques to identify and classify the sentiment or emotion expressed in the text, whether positive, negative, or neutral. Sentiment analysis provides valuable insights into public opinion, attitudes, and emotional responses.
- Network analysis [28] examines the relationships and connections between entities in a network. In the context of web content analysis, it involves mapping the links and connections between websites, social media accounts, or other online platforms. This methodology helps researchers understand online networks' structure, influence, and information flow, identifying key nodes, clusters, and communities.
- Corpus linguistics [29] involves the study of extensive collections of textual data, known as corpora. Researchers analyze web content by extracting linguistic patterns, frequencies, and co-occurrences of words and phrases from the corpus. This methodology allows for quantitative analysis of language usage, semantic associations, and discourse characteristics within a specific domain or topic.
- Discourse analysis [5, 6, 15–17] focuses on studying language use in social contexts and constructing meaning. It examines how language shapes and reflects social interactions, power dynamics, and ideologies. Researchers analyze web content to uncover underlying discursive practices, rhetorical strategies, and the social implications of language choices.
- Web mining [30] involves extracting valuable information and knowledge from web content. It combines data mining, machine learning, and information retrieval techniques to analyze large-scale web data [31, 32]. Web mining methodologies enable researchers to discover patterns, trends, and relationships within web content, helping to uncover hidden insights and generate actionable knowledge.

Researchers use different methodologies, either separately or in combination, depending on their research goals and the type of web content they analyze. Each methodology provides distinct approaches and techniques for extracting valuable insights from the diverse and extensive range of web content. By selecting and modifying these methodologies, researchers can better understand online phenomena and societal dynamics, enabling them to answer their research questions more effectively.

3 Methodology

The use and linguistic analysis of military and political euphemisms in web communication play a crucial role in understanding the complexities of discourse surrounding armed conflicts and political events. Euphemisms [33, 34] are linguistic devices that

soften or mask the harshness of certain terms or concepts, often employed in sensitive or politically charged contexts. These euphemisms can shape narratives, influence public perception, and impact the overall discourse in military and political communication on the web.

Euphemisms in web communication [35, 36] regarding military and political matters serve several purposes. Firstly, they can serve as instruments of propaganda, employed by various actors to manipulate public opinion or present a particular narrative. Euphemisms can sway public sentiment and control the framing of the discourse by using language that obscures or downplays the true nature of events. Additionally, euphemisms can mitigate the psychological impact of conflict or politically sensitive events by providing a more palatable language framework. By substituting direct and harsh terms with less emotionally charged language, euphemisms can create a sense of distance, detachment, or even normalization of violent or controversial actions. This can profoundly affect how events are perceived and understood by the general public.

Linguistic analysis of military and political euphemisms [37, 38] in web communication involves systematically examining the language used and the underlying implications of these euphemistic expressions. Researchers employ various methodologies, including discourse analysis, corpus linguistics, and semantic analysis, to identify and analyze the usage of euphemisms within online texts. This analysis aims to uncover the rhetorical strategies employed, the intended effects on the audience, and the manipulation of language for political or military purposes.

Studying these euphemisms [37, 38] provides insights into the online sphere's power dynamics, propaganda techniques, and framing of events. It enables researchers to understand how language choices shape public perception and influence the interpretation of military and political actions. Moreover, linguistic analysis allows for a critical examination of the ethical implications of using euphemisms in web communication, shedding light on the potential manipulation and distortion of information.

However, it is essential to acknowledge that the interpretation and analysis of euphemisms require careful consideration of context, cultural factors, and the specific intentions of the communicators. The meaning and impact of euphemistic expressions can vary across different cultures and societies, highlighting the importance of a nuanced understanding of the socio-political context in which they are employed.

In conclusion, studying military and political euphemisms in web communication provides valuable insights into the power dynamics, propaganda strategies, and framing techniques employed in the discourse surrounding armed conflicts and political events. Linguistic analysis allows researchers to uncover the manipulation of language [11, 31, 39–41], investigate the effects on public perception, and critically evaluate the ethical implications of such euphemistic practices. Understanding the use of euphemisms in web communication contributes to a more comprehensive understanding of the complexities of contemporary military and political discourses.

Analyzing euphemisms in web communication involves studying the use of language to convey sensitive or taboo topics indirectly or with milder expressions. Here are some methodologies used for analyzing euphemisms in web communication:

- Corpus linguistics [29] involves analyzing extensive collections of text (corpora) to identify patterns and trends. Researchers can build a corpus of web content and search for specific euphemistic expressions or words associated with sensitive topics. Researchers can gain insights into their usage and motivations by examining euphemisms' frequency, context, and variations.
- Qualitative content analysis [25, 26] involves a systematic and interpretive examination of textual data. Researchers can conduct a qualitative web content analysis, identifying euphemistic expressions and examining their context, intent, and implications. This approach helps understand the social and cultural factors influencing the use of euphemisms in web communication.
- Discourse analysis [15–17, 36, 38] examines how language constructs meaning within social contexts. Researchers applying this methodology analyze web communication to identify euphemistic language choices and examine their social, political, and cultural dimensions. Discourse analysis provides insights into the motivations behind euphemisms, power dynamics, and the shaping of public opinion.
- Sentiment analysis [4, 23, 25] uses computational techniques to determine the sentiment or emotion expressed in text. Researchers can apply sentiment analysis to web communication to identify euphemistic expressions and examine their underlying emotional tones. This methodology helps uncover euphemisms' intended emotional impact and their effects on public perception.
- Pragmatic analysis [42, 43] studies language use in context, emphasizing the intended meaning and communicative purposes. Researchers employing this methodology analyze web communication to identify euphemistic expressions and investigate their intended meaning, the context in which they are used, and the effects on the recipient. Pragmatic analysis provides insights into the strategies employed in web communication to soften or mask sensitive topics.

These methodologies can be used individually or in combination, depending on the research objectives and the specific aspects of euphemistic language being studied. By employing these methodologies, researchers can gain a deeper understanding of the use of euphemisms in web communication, including their sociocultural implications, persuasive effects, and impact on public discourse.

Table 1 outlines the advantages and disadvantages of existing methodologies for analyzing euphemisms in web communication, along with examples of military and political euphemisms.

The examples provided are euphemisms commonly used in military and political contexts and are intended to illustrate the concept. Analyzing euphemisms in web communication requires careful consideration of the context and the intended effects of the euphemistic language being used.

Table 1 The advantages and disadvantages of existing methodologies for analyzing euphemisms in web communication

Methodology	Advantages	Disadvantages	Examples of euphemisms
Corpus linguistics [29]	Provides a quantitative analysis of euphemistic usage	May lack in-depth contextual understanding	"Collateral damage" (for civilian casualties)
	Allows for identification of common euphemistic phrases	It does not capture the speaker's intent or motivation	"Enhanced interrogation" (for torture)
Qualitative content analysis [25, 26]	Provides a rich understanding of social and cultural context	Subjective interpretations may vary	"Strategic realignment" (for military withdrawal)
	Captures nuances and underlying meanings of euphemisms	A time-consuming process that requires extensive coding	"Friendly fire" (for accidental attack on own forces)
Discourse analysis [15–17, 36, 38]	Examines power dynamics and social implications of euphemisms	Requires expertise in linguistic and sociocultural analysis	"Ethnic cleansing" (for genocide)
	Explores the construction of meaning and persuasive effects	Subject to researcher bias and interpretation	"Preemptive strike" (for initiating aggressive action)
Sentiment analysis [4, 23, 25]	Provides insights into emotional tones of euphemisms	It may not capture the subtleties of euphemistic language	"Collateral benefits" (for unintended positive outcomes)
	Enables analysis of public perception and sentiment	Relies on the accuracy of sentiment classification algorithms	"Peacekeeping operations" (for military intervention)
Pragmatic analysis [42, 43]	Examines intended meaning and communicative purposes	Highly context-dependent, requires detailed analysis	"Personnel reduction" (for downsizing or job cuts)
	Focuses on the pragmatic functions of euphemisms	Subject to interpretation and potential ambiguity	"Noncombatant evacuation operation" (for civilian evacuation)

4 Results and Discussion

Social change is inevitably reflected in language. When social development is under stress, the spoken language reacts by becoming saturated with the usually abusive, absent-minded vocabulary people use to express their negative emotions. In response,

the opposite process also occurs—the language produces euphemisms, neutral counterparts to rude, obscene, or emotionally charged words, at a faster pace. Euphemization of speech, according to researchers, "ensures tolerant communication, makes it richer, and contributes to the formation of respect for speakers" [44]. In addition, the euphemization of speech, in our opinion, is also an indication of self-respect and self-irony and one of the distinctive features of the Ukrainian mentality. Studying the modern Ukrainian military sociolect [45, 46] euphemisms, we have identified several categories of lexical units that differ in their semantic and stylistic characteristics and the type of connection with the lexeme undergoing euphemization [47–49].

The most interesting layer of euphemisms is witty expressions that have no semantic connection with the concept they nominate but reveal a clear emotional association. They appear in the language as a result of an ironic perception of modern Russian propaganda, such as *піти на концерт до кобзона —to go to a concert to a kobzon; бавовна, бавовнятко—cotton, cottonwood* (see Fig. 1)*; один народ—one people* (see Fig. 2)*; бойові комарі, аналоговнєт, затридні—fighting mosquitoes, analog net, zatrydni* (see Fig. 3).

The statistics of queries show that some of them have such a transparent associative field that they do not require explanation. For example, *вирушити вслід за російським військовим кораблем* (see Fig. 4)*—follow the Russian warship* (a euphemism for the famous phrase of a Ukrainian border guard "Рускій воєнний корабль, пішов нах#й—Russian warship, go to hell") (see Fig. 4), *аналоговнєт—analogovnet* (about outdated military equipment, for which, according to Russian

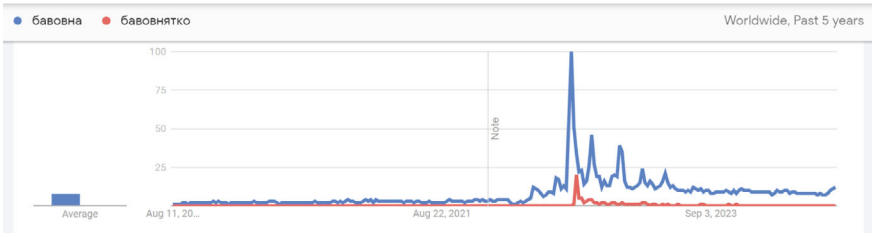

Fig. 1 The result of the search in Google Trends by keywords "бавовна" and "бавовнятко" for the past five years worldwide

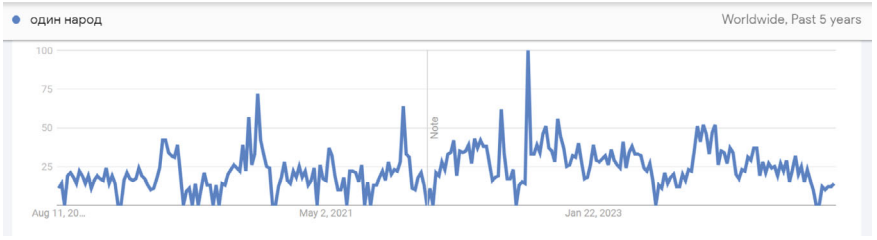

Fig. 2 The result of the search in Google Trends by keywords "один народ" for the past five years worldwide

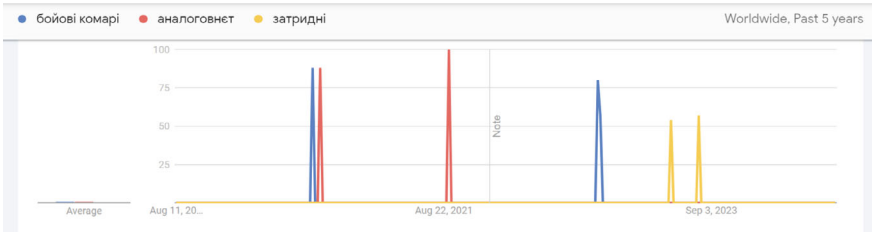

Fig. 3 The result of the search in Google Trends by keywords "*бойові комарі*", "*аналоговнєт*", "*затридні*" for the past five years worldwide

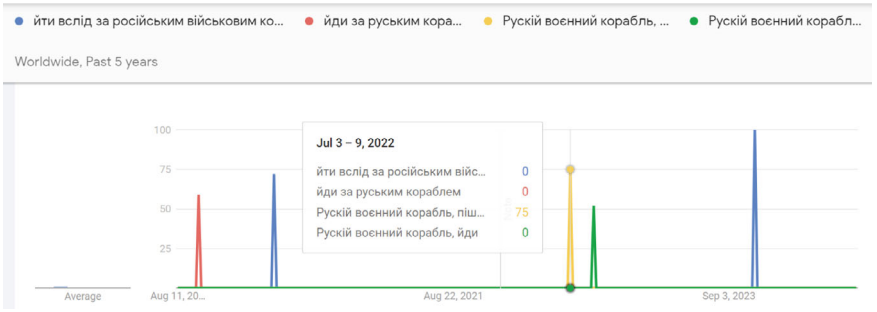

Fig. 4 The result of the search in Google Trends by keyword "*вирушити вслід за російським військовим кораблем*" for the past five years worldwide

propaganda, there are no analogs in the world), *затридні—in three days* (about the poor quality of the military operations, as the Russians planned to capture Kyiv in three days).

Others arouse considerable interest among users who want to know the etymology of the lexeme. For example, the word *cotton*, which appeared as a result of a witty translation of the Russian word *хлопок (cotton)*, was used by propagandists to refer to the concept of " *вибухи на тимчасово окупованій території України та на території РФ—explosions in the temporarily occupied territory of Ukraine and in the territory of the Russian Federation.*" The lexical equivalent of this word, but with *a* changed accent, is the word *cotton* in Ukrainian. Changing the accent and translating it into Ukrainian is a rather lengthy process of transformation, so obviously, an average Internet user is looking for information about the meaning and origin of this lexeme through search engines.

The second group of euphemisms appears due to the metaphorization of commonly used words, so the primary meaning of the lexeme causes a distinct (sometimes emotional) association:

- *дискотека—disco* (massive shelling—association due to the noise caused by both activities),

- *мопед* (see Fig. 5)—*moped* (Shahed-type drone—association due to the similarity of sound when both vehicles move),
- *зеленка* (see Fig. 6)—*zelenka* (overgrown, bushes, wooded area - similarity in color),
- *пташка—bird* (unmanned aerial vehicle—similarity in the way of movement; the affectionate suffix -к(а) indicates a positive connotation),
- *ленточка* (see Fig. 7)—*ribbon* (a column of military equipment - similarity in appearance),
- *прилiт* (see Fig. 8)—*arrival* (an explosion caused by a missile or drone strike that "arrived"—similarity in accompanying action),

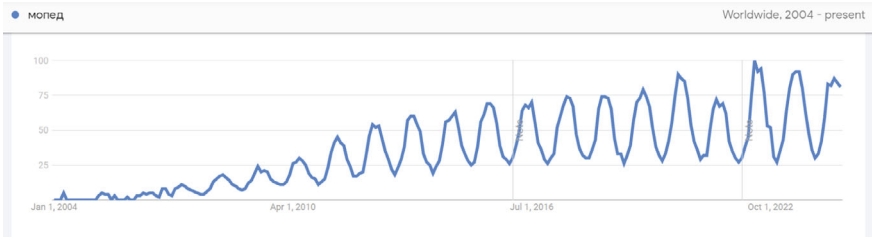

Fig. 5 The result of the search in Google Trends by keyword "*мопед*" from 2004 to 2024 worldwide

Fig. 6 The result of the search in Google Trends by keyword "*зеленка*" from 2004 to 2024 worldwide

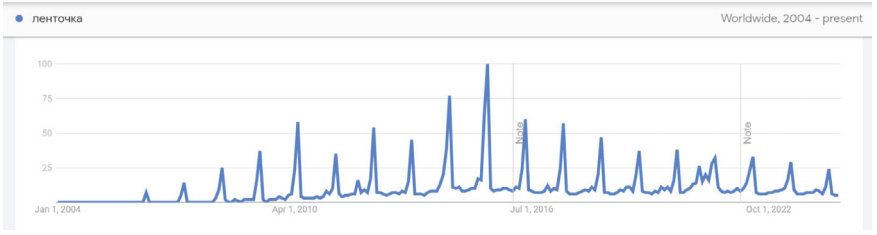

Fig. 7 The result of the search in Google Trends by keyword "*ленточка*" from 2004 to 2024 worldwide

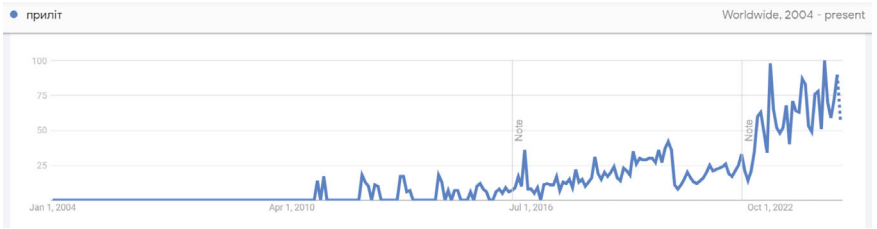

Fig. 8 The result of the search in Google Trends by keyword "*приліт*" from 2004 to 2024 worldwide

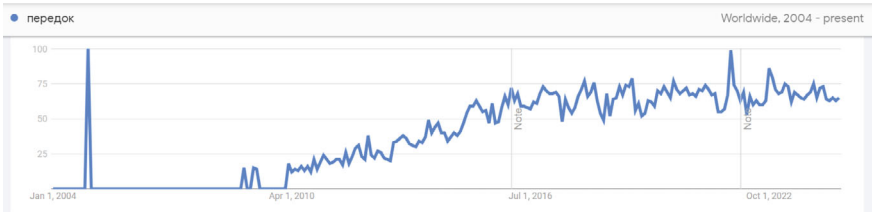

Fig. 9 The result of the search in Google Trends by keyword "*передок*" from 2004 to 2024 worldwide

- *соняшники—sunflowers* (thanks to the famous meme about a woman who told the occupiers, "Put seeds in your pockets, so that when they kill you, sunflowers will sprout"—an association with the belief in the destruction of the occupiers),
- *передок* (see Fig. 9)—*front line* (the front line of defense—similarity in location), cotton pads (a collective image of Russian pseudo-patriotic cattle—association with cheap cotton jackets popular in the Soviet empire).

The third group includes lexemes borrowed from famous movies that are popular in the modern global environment, so they are usually semantically transparent:

- *кіборги—cyborgs* (creatures with superhuman strength, superhumans—an association with the resilience of Ukrainian soldiers)—the name of the Ukrainian defenders of the Donetsk airport (see Figs. 10, 11, 12, 13 and 14);

Figure 14 shows the result of a Google Trends search for the keywords "кіборги," "cyborgs," and "киборги" for the past five years in Ukraine.

- *аватар, смурфик—avatar, smurf* (these movie characters had blue skin—an association with skin color)—about a drinker of strong drinks whose skin color turns bluish;
- *орки—orcs* (evil Horde creatures, similar to humans but with animalistic features—association with barbarism, savagery)—about Russian invaders who are abnormally cruel, wild, and ill-mannered;

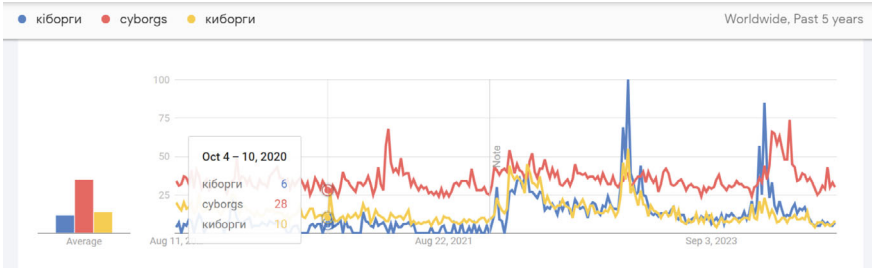

Fig. 10 The result of the search in Google Trends by keywords "*кіборги*", "*cyborgs*", "*киборги*" for the past five years worldwide

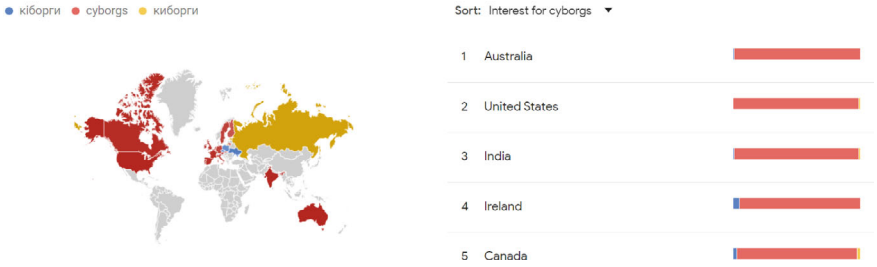

Fig. 11 The result of the search in Google Trends by keyword "*cyborgs*" for the past five years worldwide by the country

Fig. 12 The result of the search in Google Trends by keywords "*кіборги*" for the past five years worldwide by the country

- *Оркостан—Orkestan* (the country of orcs, from the Old English country of "demons of hell"—association with savagery and cruelty)—about the Russian evil empire.

The fourth group includes symbols derived from military slang:

- *мінус—minus* (shells that are launched in the direction of the enemy),

Fig. 13 The result of the search in Google Trends by keywords "*кіборги*" for the past five years worldwide by the country

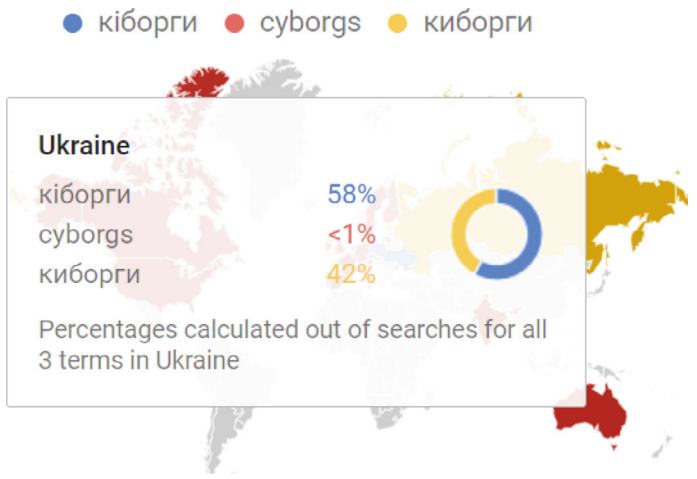

Fig. 14 The result of the search in Google Trends by keywords "*кіборги*", "*cyborgs*", "*киборги*" for the past five years in Ukraine

- *мінусувати—to minus* (to destroy the enemy)—because of the symbol used to denote the subtraction of something;
- *нуль—zero* (advanced positions on the demarcation line)—because of the distance of zero kilometers from the front;
- *піксель—pixel* (Ukrainian military camouflage)—a lexeme that serves as the name of the concept of "the smallest unit of the digital image in computer graphics" (see Fig. 15), has undergone a metaphorical rethinking due to the use of digital methods to create a camouflage image;
- *двохсотий—two hundredth* (fallen soldier)—from a conventional coded designation in the army during the air transportation of the body of a fallen soldier to the place of burial;
- *трьохсотий—three hundredth* (wounded soldier)—from the number of the form filled in by the commander to record the wounded;

Fig. 15 The result of the search in Google Trends by keyword "*піксель*" the past five years worldwide

- *п'ятисотий—five hundredth* (Russian refusenik, deserter)—from the coded designation in the army.

The search results on Google Trends for the keywords "двохсотий," "трьохсотий," "п'ятисотий" over the past three years in Ukraine are displayed in Fig. 16 and worldwide in Fig. 17.

The fifth group includes lexemes derived from proper names (places, surnames, types of weapons, etc.): *джевелінити, стінгерити, чорнобаїти, макронити, кадирити, арестовлення—dzhevelinyty, stinheryty, chornobayity, makronyty,*

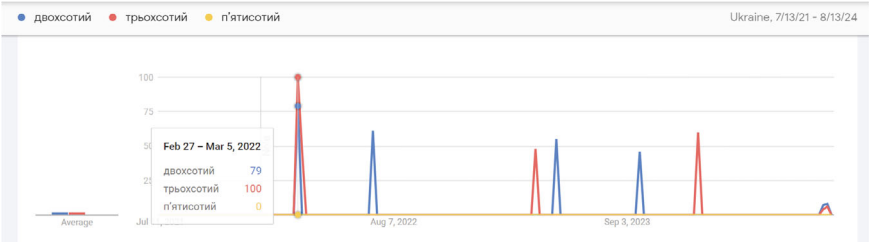

Fig. 16 The result of the search in Google Trends by keywords "*двохсотий*", "*трьохсотий*", "*п'ятисотий*" the past three years in Ukraine

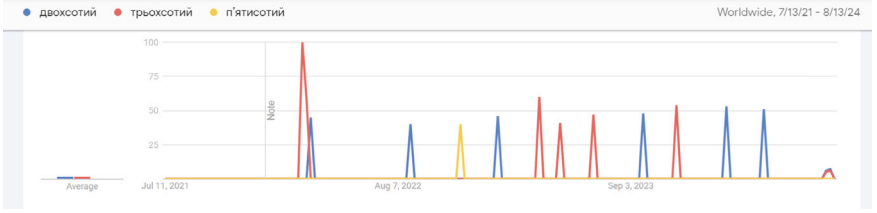

Fig. 17 The result of the search in Google Trends by keywords "*двохсотий*", "*трьохсотий*", "*п'ятисотий*" for the past three years worldwide

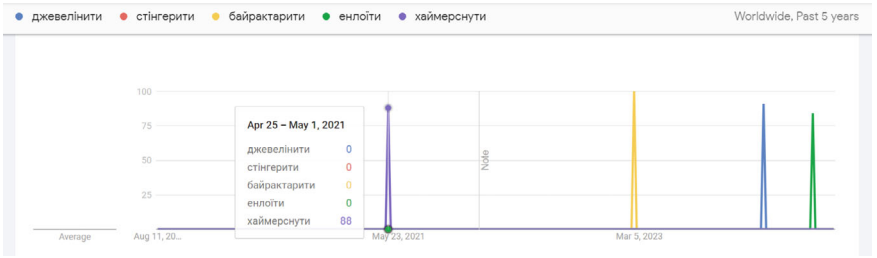

Fig. 18 The result of the search in Google Trends by keywords *"джевелінити", "стінгерити", "байрактарити", "енлоїти", "хаймерснути"* from 2004 till 2024 worldwide

kadyryty, arestovlennya. The use of this type of lexemes requires additional knowledge about types of weapons, the character or activities of famous people, and situations specific to a particular area:

- *джевелінити, стінгерити, байрактарити, енлоїти, хаймарсити, хаймерснути—javelinite, stingerite, bayraktarite, enloite, heimarsite, heimersnite*—to use the appropriate types of weapons in combat (see Fig. 18);
- *maronite* (to feign concern)—from the name of French President Emmanuel Macron, who was remembered at the beginning of the war for his concerned look rather than real help;
- *кадирити—kadyryty* (wishful thinking)—from the name of the head of Chechnya, Ramzan Kadyrov, who has repeatedly threatened to capture Ukraine and posted videos of imaginary battles online (see Fig. 19);
- *арестовити—arrestovyty* (to calm down), *арестовлення—arrestavlennya* (to deliver calming messages)—from the name of the former advisor to the Office of the President of Ukraine, Oleksiy Arestovych, who, with his manner of communication in the first weeks of the full-scale Russian-Ukrainian war, inspired a calming mood in Ukrainians (see Fig. 20);
- *чмоня, чмобик—chmonya, chmobik* (suffixes from the word *chm*—an unpleasant person who causes disgust, disgust)—a Russian soldier in primitive equipment and with external signs of alcoholism (see Fig. 21);

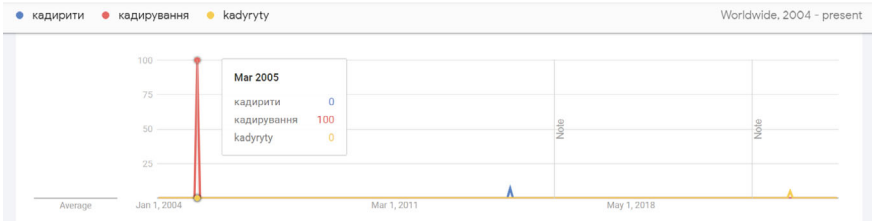

Fig. 19 The result of the search in Google Trends by keywords "*кадирити*", "*кадирування*", "*kadyryty*" from 2004 to 2024 worldwide

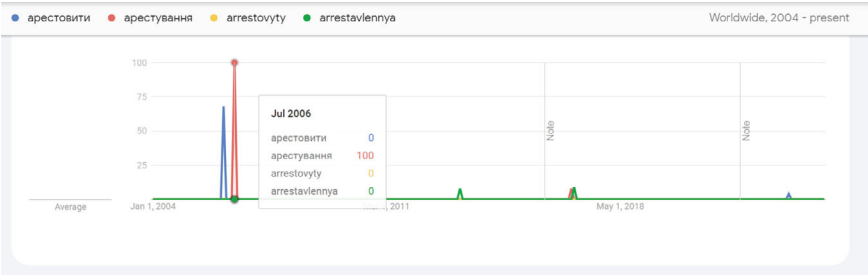

Fig. 20 The result of the search in Google Trends by keywords "*арестовити*", "*arrestovyty*", "*арестовлення*", "*arrestavlennya*" for the past three years worldwide

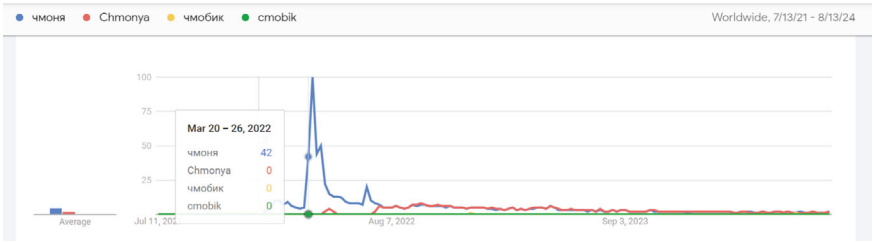

Fig. 21 The result of the search in Google Trends by keywords "*чмоня*", "*chmonya*", "*чмобик*", "*chmobik*" for the past three years worldwide

- *бандеромобіль—banderomobile* (improvised armored vehicle)—from the name of the leader of Ukrainian nationalists Stepan Bandera with a clear hint of the task of this vehicle—to destroy the occupiers (see Fig. 22);
- *чорнобаїти—chornobaity* (to inflict regular losses on the enemy)—from the name of the village of Chornobaivka near Kherson, where the occupiers stored their equipment at the seized airport, which was destroyed dozens of times by the Armed Forces of Ukraine (see Fig. 23).

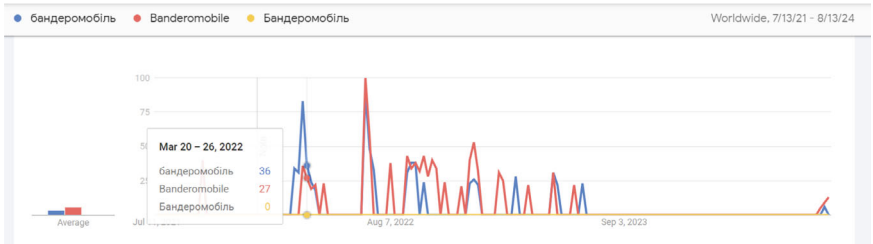

Fig. 22 The result of the search in Google Trends by keywords "*бандеромобіль*", "*banderomobile*", "*Бандеромобіль*" for the past three years worldwide

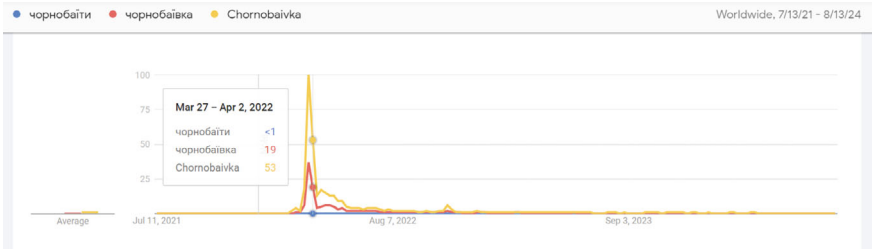

Fig. 23 The result of the search in Google Trends by keywords "*чорнобаїти*", "*чорнобаївка*", "*Chornobaivka*" for the past three years worldwide

This proper name has also become part of several well-established expressions: *Chornobaivka Day* (reinforced by the association with the famous movie Groundhog Day, in which the same events repeat themselves every day), *Chornobaivka Triangle* (reinforced by the association with the Bermuda Triangle, in which everything disappears into the unknown), *Chornobaivka effect*, etc.

The sixth group of euphemisms is word combinations based on a phraseology or a well-known expression but paraphrased by current associations. Examples involving the name Chornobaivka are given above. Here are a few more such euphemisms.

- *Клеїти шольца—playing the Scholz*—by analogy with the phrase " *playing the fool* "—constantly promising help but actually doing nothing; associated with the indecisive behavior of German Chancellor Olaf Scholz (see Fig. 24).
- *Привид Києва*—the *ghost of Kyiv*—by analogy with the popular Soviet expression, the *ghost of communism*—is a collective image of Ukrainian pilots who defended the Ukrainian sky over Kyiv (see Fig. 25).
- *На щиті—on the shield*—a shortened version of the ancient expression "with a shield or on a shield" used by women of Ancient Sparta to send their husbands off to war and wish them to return victorious (with a shield) or to die for the Motherland (on a shield)—means the return home of a fallen Ukrainian soldier (see Fig. 26);
- *бандерівське смузі—Bandera smoothie*—by analogy with the famous expression *Molotov cocktail*—a homemade incendiary mixture (see Fig. 27).

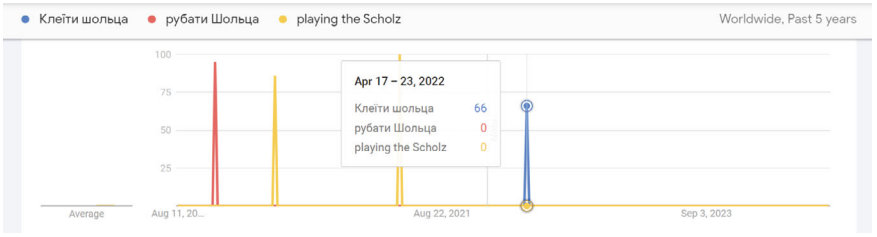

Fig. 24 The result of the search in Google Trends by keywords "*клеїти шольца*", "*рубати Шольца*", "*playing the Scholz*" for the past five years worldwide

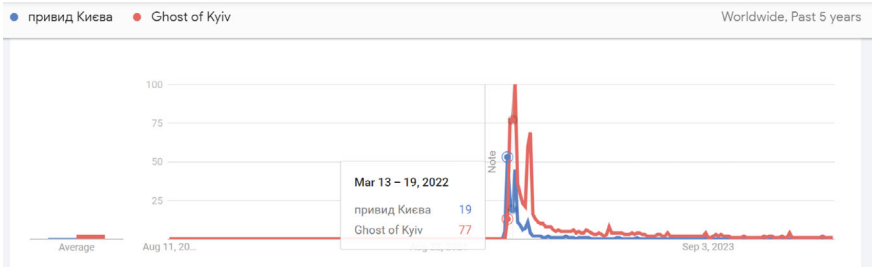

Fig. 25 The result of the search in Google Trends by keywords "*привид Києва*", "*Ghost of Kyiv*" for the past five years worldwide

Fig. 26 The result of the search in Google Trends by keyword "*на щиті*" for the past five years worldwide

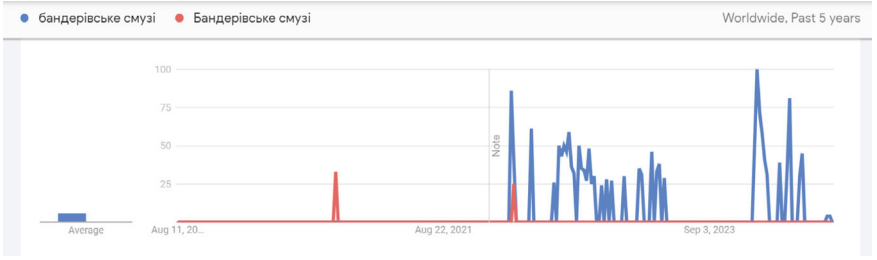

Fig. 27 The result of the search in Google Trends by keyword "*бандерівське смузі*" for the past five years worldwide

The seventh group of euphemisms are words formed as a result of the contamination of two lexemes with a clear hint of the corresponding associations, which are so transparent and understandable that euphemisms of this group do not require additional interpretation:

- *русня* (росіяни + х__ня)—*Rusnya* (Russians + shit), see Fig. 28,
- *рашисти* (росіяни + фашисти)—*rashists* (Russians + fascists), see Fig. 29,
- *путлер* (Путін + Гітлер)—*Putler* (Putin + Hitler), see Fig. 30,

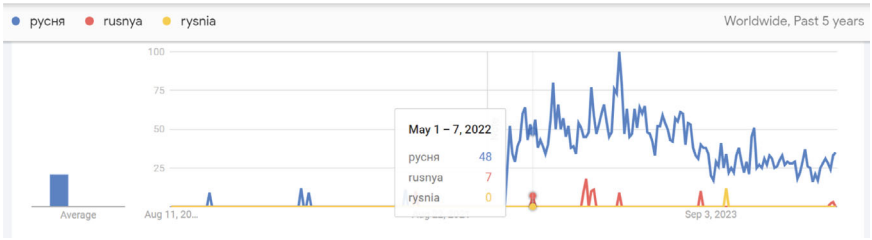

Fig. 28 The result of the search in Google Trends by keywords "*русня*", "*rusnya*", "*rusnya*" for the past five years worldwide

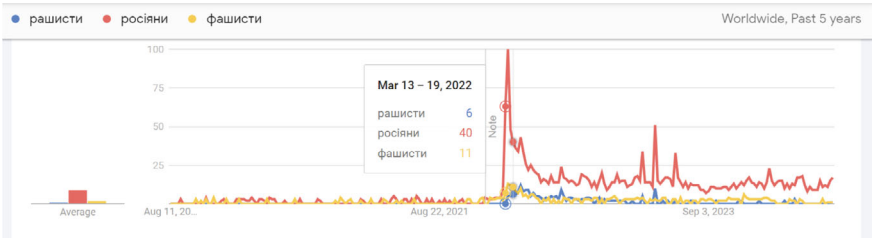

Fig. 29 The result of the search in Google Trends by keywords "*рашисти*", "*росіяни*", "*фашисти*" for the past five years worldwide

Fig. 30 The result of the search in Google Trends by keywords "*путін*", "*Putler*" for the past five years worldwide

- *Релаксович* (релаксувати + Арестович) тощо—*Relaksovych* (relax + Arestovych), see Fig. 31.

The eighth group of euphemisms is lexemes based on borrowed morphemes devoid of expressive connotations. Usually, euphemisms of this group were formed through the slang use of socio-political terms. For example, *сепари* (see Fig. 32)—*sepery* (instead of *traitors*) comes from the Latin term *separatism*, which means "political movement for separation from the state"; *мультик—cartoon* is a universal camouflage color for different areas; it comes from the Latin *multi*, the first part of

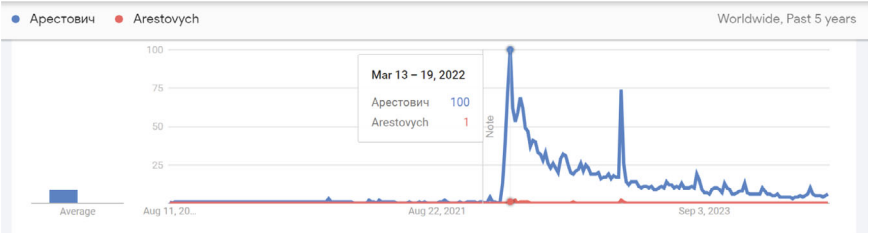

Fig. 31 The result of the search in Google Trends by keywords "*Арестович", "Arestovych"* for the past five years worldwide

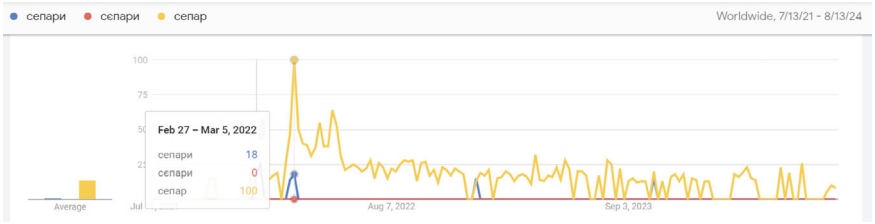

Fig. 32 The result of the search in Google Trends by keywords "*сепари", "сєпари", "сепар"* for the past three years worldwide

compound words, which means a plurality of objects or the multiplicity of some actions or functions.

The emergence of numerous euphemisms demonstrates the unique, expressive capabilities of the Ukrainian language, confirms its inexhaustible creative potential, and presents the intellectual wit of Ukrainians who, in the complex, stressful situation of war, do not resort to rude language but try to maintain high morale by using accurate humorous or neutral lexemes instead of emotionally complex ones with negative semantics. Each euphemism analyzed reflects unwavering confidence in victory, wit, and the ability to notice details, an essential component of the original development of the Ukrainian language in times of war.

After conducting our analysis, we found that euphemisms play a significant role in Ukrainian military and socio-political discourse, especially in the context of the Russian-Ukrainian war. These euphemisms are used as a linguistic tool to soften the harsh realities and reflect the cultural and emotional responses of the Ukrainian people to ongoing conflicts. The wide variety of euphemisms, ranging from witty and ironic expressions to those rooted in military slang and popular culture, demonstrates the adaptability and creativity of language in times of crisis.

Categorizing euphemisms into distinct groups based on their semantic and stylistic characteristics can provide a deeper understanding of how language evolves to address sensitive topics. Euphemisms derived from metaphorization, military slang, and proper names illustrate these expressions' layers of meaning and socio-political

nuances. Additionally, using euphemisms influences public perception and plays a role in shaping national identity and resilience.

The data gathered from Google Trends confirms that euphemisms are widely used and understood in the Ukrainian context, showing their significant role in modern conversation. However, it is important to remember that while euphemisms can make it easier to talk about complex topics, they can also make the seriousness of certain situations unclear, leading to different interpretations and emotional impacts.

Studying euphemisms in Ukrainian web communication offers valuable insights into the intricate interplay between language, culture, and war. It emphasizes the significance of context and cultural awareness in analyzing linguistic phenomena, particularly in politically charged environments. As the war develops, the language used to describe it will also change, making ongoing analysis essential for understanding Ukraine's constantly evolving military and political discourse landscape.

5 Conclusion

This study shows that using computer-based content analysis to study web communication about the Russian-Ukrainian war can help us understand the complex dynamics of how people talk about conflicts. By looking at euphemisms, the research reveals how language influences public opinion, conveys emotions, and hides the true impact of war. Euphemisms are powerful tools in propaganda and public discussions, shaping stories and affecting how we see the world.

The analysis identified various categories of euphemisms. These ranged from witty expressions without a direct connection to metaphorical phrases. They also included borrowed words from popular culture, military slang, and proper names. These euphemisms show how language can be creatively adapted in response to conflict, reflecting the cultural and emotional currents within societies. The findings emphasize the importance of understanding the socio-political context in which these euphemisms emerge. Their meanings and impacts can vary significantly across different cultural and temporal contexts.

In addition, the study highlights the importance of using various methods, such as corpus linguistics, qualitative content analysis, discourse analysis, sentiment analysis, and pragmatic analysis, to understand euphemistic language use fully. Each method provides different insights into how euphemisms work in online communication, and together, they offer a complete understanding of the relationship between language, power, and perception.

In conclusion, this research contributes to the linguistic understanding of euphemisms in the context of the Russian-Ukrainian war and offers broader implications for studying conflict communication in digital spaces. The study reveals the strategies behind euphemistic language and its impact on public discourse, providing a foundation for future research to explore the ethical implications of language manipulation and the role of digital communication in shaping contemporary conflicts.

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Knowledge Management and Business Processes in CEE Service Centers

Ümit Güfte Peköz

Abstract The objective of this research study is to examine the application and acceptance of knowledge management (KM) tools and methodologies in CEE BPO service centers. The research will employ a case study research design with embedded units to investigate how competitiveness is understood and reflected in management decision-making and operational practices within BPO centers. The study aims to provide insights to team members, particularly decision-makers and managers in the CEE region, by highlighting the current situation and future potential for sustainable competitive advantage. The study found that language skills, especially in the customer's mother tongue, are crucial for delivering high-quality service. Additionally, the research revealed that an attractive legal framework that supports personal leasing for center operations, along with taxation benefits for service centers in the EU zone, is common practice to control personnel costs and make the region appealing for service center establishment. Center managers face the challenge of balancing innovation creation activities with the pressure to deliver efficient services in terms of cost, resources, and quality.

Keywords Knowledge management · BPO · CEE · Competitive advantage · Innovation · Service centers · Outsourcing

1 Introduction

The rise of Business Process Outsourcing (BPO) and service centers in Central and Eastern Europe (CEE) has greatly changed the global outsourcing industry over the last twenty years. As these centers have matured, they are under increasing pressure to maintain their competitive advantage in a rapidly changing market. This research aims to explore how knowledge management (KM) tools and methods are used and

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embraced in CEE BPO service centers, with a specific focus on their role in promoting innovation and maintaining competitive edge.

The study uses a case study approach focusing on service centers in Bratislava, Slovakia, to investigate how competitiveness is perceived and how it impacts decision-making at both managerial and operational levels. By analyzing the existing knowledge management practices, innovation processes, and competitive strategies, this study aims to offer valuable insights for stakeholders in the CEE BPO industry.

As the global outsourcing market evolves and low-cost countries emerge as new competitors, it is essential for service centers in Central and Eastern Europe (CEE) to make the most of their expertise, language skills, and geographical location. This research explores how these centers adjust their strategies to shift from competing based on costs to providing value-added services that take advantage of their unique strengths. In this study, we delve into the relationship between knowledge management, innovation, and sustainable competitive advantage by conducting thorough interviews with center managers and operational leaders. Our aim is to provide insight into the challenges and opportunities encountered by CEE service centers as they transition from basic task execution to more intricate, knowledge-driven operations.

The findings from this research will add to the existing body of literature on knowledge management in the context of BPO operations. The research will also offer practical recommendations for CEE service centers seeking to improve their competitiveness in the global market. This study aims to support the strategic decision-making processes of BPO centers in the CEE region and beyond by exploring the role of knowledge management in driving innovation and maintaining a competitive edge.

2 Methodology

For this research, a case study research design is considered suitable because the main goal is to investigate how knowledge management tools and methodologies are utilized and embraced in CEE BPO service centers. This type of research design is appropriate when the researcher has no control over the context or variables in the study, and the objective is to address "how" and "why" questions. In qualitative research, the results are not intended to be representative or generalized from the findings; instead, the focus is on comprehending the connections between events within a specific context [1]. This research study investigates how competitiveness is perceived in CEE BPO service centers and how it influences decision-making at the management and operational levels. The objective is to provide insights that can be used to advise CEE centers on enhancing their competitiveness. The findings will help all stakeholders identify areas where their policies are effective and improvements are needed. Bratislava was selected to represent the CEE region due to its similarity to the demographic characteristics of CEE center employees in general.

This study aims to provide valuable insights for team members working in CEE BPO centers, particularly decision-makers and managers. It highlights the current

situation and future potential for achieving sustainable competitive advantage in the CEE region, with a specific focus on Bratislava [1].

To thoroughly understand the current state of Knowledge Management (KM) and its practical applications, it is crucial to thoroughly review the theoretical background and current research findings related to KM [2], innovation, and sustainable competitive advantage. It is also important to demonstrate the benefits of using KM tools in organizations to propose relevant ideas for further evaluating the research findings in this study.

This research is designed to be an exploratory single case study with embedded units. The goal is to investigate the awareness level of involved parties in centers regarding the importance and identification of competitive advantage enablers such as KM tools in their process areas or operations. The research aims to discover new factors without being limited, as the CEE Region has not been fully researched independently up to this point. The research intends not to compare different service centers but to explore the current state and identify the managerial and operational practices in place to maintain and secure a sustainable competitive advantage [3].

This study involves all individuals in CEE BPO centers, particularly decision-makers, and managers, by highlighting the current situation and future potential for sustainable competitive advantage in the CEE region. The practical study demonstrates how knowledge management tools are considered in strategic decisions in CEE BPO centers and how they are used and applied in operations.

Initially, the plan was to conduct four to ten 40–60 min episodic interviews with volunteer center managers and operational leaders in different BPO or service centers in Bratislava [4]. However, the final number of respondents varied due to the information needed to answer the research question and considering the potential strengths and weaknesses of the data obtained. More details on the episodic interview method, the reasons for choosing this interview type, and further details on analyzing the interview data are provided. In total, six interviews were conducted at two of the largest service centers in Bratislava. The interviewees were contacted through a professional network and friends working in CEE BPO and service centers. In some cases, interviews were granted as a favor to a student. It was challenging to obtain permission for interviews as confidentiality contracts bind most service center employees. However, HR permission was obtained for this academic study with the assurance that no results would be linked to any specific organization or individual. To protect organizational and personal data, no names were recorded in the research. Interview metadata only included the center's size, operational activity area, and the interviewee's managerial or operational responsibilities. The goal was to maintain business confidentiality and protect organizations from strategic exposures.

The data collection process followed a circular pattern based on theoretical sampling [5]. After each interview, we reflected on the questions asked, and the answers received, considering potential modifications. This reflection influenced the decision on the questions for the next respondent, with the goal of obtaining the most relevant data to address the research questions. This process of theoretical sampling continued until a point of saturation was reached for the findings. The first interview served as a pretest to assess the question construction and interview flow. The

research design included interview guidelines for episodic interviews in line with theoretical sampling [6].

2.1 Research Methods and Data Collection

The empirical research of this study incorporated the consonant qualitative methods of data collection and data analyses [7]. The method of episodic interviews was chosen for data collection [6], which was intended to provide information about the usage of KM in daily operations by challenging the response's simultaneous integration of episodic and semantic levels. As an appropriate analytic method the combination of thematic analysis and system analysis was chosen, which corresponds with the chosen data collecting method. This combination made it possible to investigate the complex social systems and process dynamics to answer the research question of this study about usage of KM in CEE BPO centers.

The study used episodic interviews to collect data, as it helps differentiate between episodic and semantic knowledge, making it effective in understanding the daily use of Knowledge Management (KM) [6]. The aim of the research was to determine the implementation of KM and whether it becomes a regular practice in daily routines. Therefore, it was crucial to not only identify verbal statements and extract their meanings (semantic knowledge) but also to capture the memories and experiences individuals have with specific technologies (episodic knowledge) explicitly. Episodic interviews were chosen to gain deeper insights into individuals' daily routines and to understand their subjective perceptions of the benefits provided by KM tools [6].

This method can help us verify if the statements made are actually being applied in daily tasks. To conduct an episodic interview, guidelines have been created to help the interviewer focus on the topics being researched. Since an episodic interview involves open questions and the interviewee should not be led with questions, this guideline is considered necessary. In this data collection method [8], it is important to identify a person's experience with KM tools and practices.

2.2 Data Analyzing and Evaluation

The statements mentioned above are based on a review of theoretical literature and the current state of research on the topic of knowledge management. Conducting a thorough analysis of the findings will allow us to evaluate the research statements and determine whether to accept or reject them based on the relationships between them. We will analyze the data using a combination of thematic and systems analyses in order to connect the findings to the previously mentioned statements, as well as to explore new related areas of interest.

In order to ensure the quality of a qualitative research study, it is crucial to select an appropriate analysis method. While there is no fixed formula for conducting

qualitative analyses, there are guidelines to follow [9]. For this qualitative research, the thematic analysis method is deemed suitable, as the aim is to identify patterns in experiences with KM in daily operations and gain insight into an individual's routines. Thematic analysis enables the identification of both explicit and implicit meanings or statements, allowing systematic coding, pattern identification, and data interpretation [10].

Through this analysis, it becomes possible to group and categorize the numerous statements in transcripts. Using coding, grouping, classifying, and assigning the identified significant statements to KM within thematic frameworks, the findings can be assessed. The process of thematic analysis can be conducted in many ways depending on the research design and the question, but some common approaches are suggested, and these guidelines are adopted as follows:

First run: Review and read all the transcripts to identify if similar themes can be determined while preliminary coding can start. Using the interview guidance it can be determined which themes are common as well as which new themes are found.

Second run: Transcript text can be reduced by coding and collating it under existing and newly identified themes. Creating categories according to related codes can facilitate pattern-building and theme identification. In analyzing the text, special attention needs to be paid to understanding whether some statements are expressed by respondents themselves or only after a concrete question is given by the interviewer.

Third run: All the themes should be listed, including new topics, as well as the relationships between themes, and their research focus should be identified. At this stage, it should also be determined which themes and statements are missing.

Fourth run: A comparison analysis should be run between different themes to locate similarities and differences, which should help us recognize patterns to support or oppose previously identified themes. The point is not to homogenize the data but to take critical consideration of the contradictory statements. In this step critical questioning will take place, such as if themes are bringing out some underlying ideas or interpretations of the analyzed data.

Fifth run: Clear definition of which themes exist and what is essential to them. Their characteristics should be documented to see if it is possible to integrate these findings together with the research questions. Finding differences in patterns can signal a need for deeper analysis or for further research.

Final run: To decide how to proceed, a rough draft of the results should be made, showing themes and their relation to research interest. At this point, it must be decided whether it is worth repeating the process to see if any detail is overlooked or not fully represented in the findings.

In this approach it is critical to identify what is a theme [9], since just finding repeated statements or topics is not sufficient to identify the findings as a theme. Any theme found should be relevant to the research focus and questions, as well as to the theory. Bryman further suggests monitoring linguistic connectors (since, because, etc..) in statements, as well as specific expressions and technical terminology together with a theme transition [9].

The thematic analysis allows us to identify patterns and overall themes expressed during an interview. It helps us explore within a given context and uncover the deeper

meanings of what is said. System analysis complements this method by identifying and clarifying what these themes represent within the context of social norms and functions (Lueger, 2010). System analysis helps explain, at a deeper level, how the observed social system came into existence (Lueger, 2010). In our case, it helps us understand the innovative capability and the state of knowledge management by CEE center managers.

The authors of thematic analysis and system analysis suggest combining these two methods to investigate complex social systems and process dynamics. System analysis aims to interpret extensively from statements that are not clearly expressed or latent and to explain the structuring elements with relevance to their contexts and subjective meaning for the individuals involved (Lueger, 2010).

In the second detailed analysis process, the data is evaluated to uncover the social context that was in place and how it influenced a person's use and experience of certain KM tools or systems. By analyzing implicit statements, it becomes possible to discover underlying meanings, assumptions, or interpretations of the collected data. The system analysis operates on three levels:

1 Paraphrasing or reformulating selected statements into a simplified form.
2 Analyzing the semantic level to emphasize the close and broad environmental and personal context present around a person.
3 The third level involves the hypothetical context framework.

The system analysis process follows a three-phase matrix structured framework to generate 5 outputs from a transcript section. The first phase starts with paraphrasing the chosen transcript section, the second phase investigates the themes and the text frameworks from a point view of an interviewed person but not from a point view of a researcher. The third phase analyzes the chosen section in a person's living environment, the fourth phase analyzes the interactional effects between identified contexts, and then the final phase analyzes the effects of the collected findings on the system level and generates the type of hypothesis (Lueger, 2010).

Lueger further suggests that the following points should be considered during the analysis process:

- Paraphrasing: Semantic content derived from chosen texts
- Statement context: Identifying why a person expressed this text in that way and form

  Text framework: What can this expressed situation mean
  Living environment: Which environmental structures and perspectives influence these expressions and statements

- Hypothetical impact context: What influence can these evaluated statements have on the dynamics of a given situation.

  Interactions effects: Which consequences should be expected from this situation
  System effects: How can these interactional effects influence the structure of a social system.

System analysis involves reconstructing a given topic by examining the connections between an individual's experiences related to the research topic and the collective meaning of their actions. It is a complex process of evaluating collected data to provide insights into how a social system is constructed, emphasizing the meaning of different statements (Lueger, 2010).

3 Results

During interviews, participants displayed varying levels of comprehension regarding competitiveness from a strategic management standpoint. They also identified different factors contributing to competitive advantage for their organizations or service centers. This discrepancy can be attributed to the fact that not all participants were actively involved in strategic decision-making with significant responsibilities in center management. However, this limitation should not undermine the findings, as it is crucial for every manager involved in center operations to be capable of articulating the threats posed by competition in the global BPO and service center market.

Upon initial reaction, some managers did not clearly identify the threats arising from low-cost countries. This could be attributed to the fact that the center functions as an internal service center for a parent company. Participants did not exhibit a clear understanding of competition among service centers, even when serving internal clients. It is essential for a global organization to determine the necessary measures for cultivating local competitiveness by actively monitoring the global BPO marketplace.

During the interviews some managers explained that, even under a strong outsourcing tendency, the parent company still tried to keep the core competencies in house, and not to outsource these activities. This was even if the insourcing might result in a higher cost, which confirms the theory that outsourcing decisions were not based only on cost calculations. This finding may help CEE BPO service centers in designing their strategic decision-making and future road-maps. Based on what participants expressed in the interviews, it can be possible to classify and to group the findings for competitiveness and competitive advantage, together with SCA, as the following.

3.1 Strategic Positioning and a Competitive Advantage

Some managers are struggling to clearly understand the competitive advantage for service centers. One manager mentioned that having low-cost employees is no longer a top priority for the organization. Instead, they are now considering the strategic perspective and exploring opportunities to outsource work to other locations. This manager also emphasized the importance of hiring the best talent to maintain competitiveness and identified themselves as part of the parent company, rather than just a

service provider. However, these managers seem to be unaware that they are providing services to their internal customers. The parent organization has the freedom to choose other service providers or to establish new centers elsewhere in the world, regardless of their existing ties with service centers in CEE. In the decision-making process, it is essential to consider the cost calculation and total cost of ownership (TCO) when making outsourcing decisions, even if it is internal outsourcing.

It appears that the manager may not fully appreciate the potential challenges posed by low-cost countries offering similar services and language support at a lower price. It seems that the manager's focus is primarily on protecting the interests of the parent company's shareholders in terms of cost considerations, and they may be willing to relocate jobs and services to a low-cost country, even if doing so could negatively impact the organization's own service center by leading to job losses and the transfer of positions to a low-cost country outside of the Central and Eastern European region.

The participants in some cases struggled to identify the critical factors for competitive advantage in a global market. They mainly perceived the competition in the BPO market at a country level while failing to recognize the global competition for customers. During interviews, participants expressed a focus on hiring top talent within Slovakia or the CEE region by offering better salaries and growth opportunities. However, they did not fully grasp the competition in retaining BPO customers within the CEE region. Their competitiveness was mainly seen against other local centers to attract talent, but they did not fully acknowledge the global challenges.

Some managers did not provide a clear definition of SCA (Sustainable Competitive Advantage) for the centers, which is crucial in designing strategies to ensure the strategic importance of knowledge management in safeguarding the SCA.

3.2 Identified Source of Competitiveness

The following topics have been identified as ways for CEE service centers to gain a competitive advantage in the BPO service center market. These identifications were not clearly made in comparison to low-cost countries, and they were presented in a general manner without naming other regions in the global market or providing a specific unique value proposition or offered in SCA. These include low-cost service provision, language skills, geographical advantages, complex service delivery, and the accumulated expertise within the service centers.

The initial reason for moving activities into Slovakia service centers was to save costs, but there is now pressure to control increasing salary levels. This is because salaries and operating costs in Central and Eastern European (CEE) countries are no longer the lowest globally. CEE service centers have successfully attracted activities from various countries and standardized processes across these countries, leading to greater efficiency and productivity than Western countries. While lower employment and living costs in CEE countries are advantageous compared to Western countries, they can be a disadvantage compared to low-cost countries in the Far East or South America. Standardizing processes and serving multiple internal clients are essential

to remain competitive. However, extensive standardization might pose a challenge to CEE Business Process Outsourcing (BPO) centers, as transferring these consolidated internal processes to external service providers in other parts of the world becomes feasible. This standardization could potentially reduce dependency on the complex knowledge that is a source of sustained competitive advantage (SCA). Additionally, low-cost strategies are deemed unsustainable in low-cost countries and within the CEE region due to significant salary level gaps. As a result, the cost advantage is expected to diminish, leading to an anticipation of job migration to Eastern countries.

Initially, most activities were seen as simple and manual tasks, such as filling out forms and validating contracts. These tasks did not require highly educated or skilled staff. However, as knowledge accumulated and more tasks were transferred to centralized centers, the complexity of processes grew significantly. This increase in complexity was primarily due to the rise in the number of stages involved in service provision and process execution. The additional steps brought complexity into the processes.

Another observed factor was the change in the relationship between the central centers and the countries. As more tasks were moved to the center, the organizational knowledge in the countries was either replaced or transferred to the central centers in Central and Eastern Europe. As a result, the support from the countries was no longer at the same level, and there was a reversal in the flow of information and knowledge. Additionally, any undocumented or exceptional situations could only be handled through the central centers, further adding complexity to the processes. The processes are becoming simpler and more globalized. This naturally means that resources should be allocated to other or additional activities. The complexity of service and process execution is regarded as a competitive advantage in the market. The provision of end-to-end services to the client is further regarded as an SCA since such services involve complex multistage process execution.

The Central and Eastern Europe (CEE) region has a distinct proximity advantage over low-cost countries and regions, especially when it comes to being closer to Western countries. However, this advantage does not extend to customers from the USA. The geographical closeness offers benefits such as similar time zones and easier travel for face-to-face meetings when necessary. This proximity significantly impacts the success of knowledge transfer and contract management. On the downside, the closeness can also be a disadvantage as employees in the CEE region are free to move within the EU job market, influencing salary levels. This geographic advantage has a negative effect on the Single Customer Average (SCA) for CEE service centers, as the low-cost advantage from lower salaries in the CEE region is not sustainable due to the open job market and ease of movement between EU countries. Moreover, most interview outcomes note a comparison of the working environment with Western Europe, while failing to mention the comparison with low-cost countries. Language Skills.

The majority of the respondents agreed that language skills are the most important factor in providing high-quality service to customers, especially when conducted in the customer's mother tongue. This presents a clear advantage for the CEE region as the European Union zone has a greater diversity of spoken languages than any

other economically significant region. Language skills are therefore considered a critical advantage over low-cost BPO service centers located in the Far East or South America. It's important to identify the main customer countries for BPO solutions and the languages spoken in those regions.

The level of standardization of processes should be examined, as highly-standardized processes are expected to become more common in business execution. In the EU zone, CEE BPO and service centers can be viewed as a stage for BPO adaptation, helping organizations to redesign, simplify, and standardize their business processes [11, 12]. It is anticipated that new models of one-to-many service provision will be the next wave in BPO practices. These findings need further analysis and research to identify future trends in the BPO market. The analysis identifies language skills as an important source of competitiveness in BPO service center operations. Centers rely on people with language skills, and it is important to determine how this critical source is managed. Some managers have agreed to offer base salaries to people with language skills, which may be seen as a gap in HRM strategy design, as these individuals are crucial for ensuring SCA in service centers.

Support levels in different countries have changed since the start, and there's been a reversal in the flow of information and knowledge. Unique or exceptional situations can now only be handled using the knowledge and experience available at the central office. This new development adds complexity to the handling of processes. As service centers develop, the level of knowledge and complexity naturally increases, along with the organization's capacity to absorb knowledge. Operating within a concentrated area has allowed the accumulation of tacit knowledge through face-to-face interactions for various processes across different countries.

High levels of knowledge concentration have been identified in the CEE service centers, giving them a competitive advantage in the BPO market compared to other regions. However, this knowledge is shared with other service centers. There is a continuous flow of knowledge identified between all service centers owned by the parent organization. This ensures organizational knowledge retention for the parent organization but weakens the service center's position against low-cost countries. This will be further discussed in the conclusion section.

The main Key Performance Indicators (KPIs) used to measure service quality and operational efficiency in the center are linked to operational indicators, such as the speed and turnaround time for processing contracts or customer requests, as well as quality levels measured through customer feedback and surveys. The focus on ensuring service quality is crucial as it is considered the best indicator of customer satisfaction [13]. This approach further supports service provision efficiency. Service provision requires a significant investment in human resources, and center managers view their employees as hardworking and committed to providing timely solutions to customers. This underscores the importance of focusing on specific elements in service center operations. Flexibility is also identified as a critical factor in service provision, as some managers leverage flexible shifts around the clock to support service operations. Additionally, an attractive legal framework supporting personnel leasing for center operations, including some taxation benefits in the CEE region,

is common practice to control personnel costs and make the region attractive for establishing service centers.

Understanding client needs and maintaining close communication with clients are also identified as a strategic competitive advantage for CEE centers. Further discussion could help analyze how unique and difficult to imitate these elements are for other centers.

3.3 Innovation as a Source of SCA

Innovation is seen to be a source of SCA in service centers, where it is understood to provide unique solutions thereby adding value to customers. Innovation can address every-day problems, overcoming difficulties in providing service quality to customers, or by increasing the efficiency of service provision. Innovation is further understood to challenge the established processes, especially where more efficiency and creativity is needed to provide better, quicker and cheaper solutions in terms of price or time.

Managerial involvement and support is seen to be innovation enabler in the centers, since new ideas and workarounds can be brought to a broader audience and get acceptance for center wide applications. Only through managerial support it can be possible to do cost benefit calculations to decide on new ideas for development: every innovation is based on an idea which needs financial and human resources to develop into an innovative solution [14]. An individual can have an idea or new work around, and applying even this small improvement in the team or organization can bring real innovation. However small improvements at an individual level cannot be regarded as an innovation. An investment decision is needed to create impact making innovative solutions, together with strategic decisions [15, 16]. More than new ideas is needed to generate innovation.

An identified barrier to innovation in the service center is the lack of a management system to support experimentation with new ideas to demonstrate innovation. There is a need for personal space to make decisions and the ability to try and fail to find new innovative practices. Overcoming the absence of a managerial system to support innovation proves challenging and appears to hinder the development of new ideas. Acceptance of innovation should be based on a common strategic goal, aligning with the expected and delivered benefits from innovation activities.

We can perform a miracle in our small world, but the larger world may not accept it due to different perceptions and structures.

One of the service centers surveyed has dedicated 24 h workshops designed as an innovation tool to help develop solutions. They bring teams into this new environment to solve identified problems. They also use mind mapping techniques for knowledge sharing and retention and a systematic approach to developing new ideas and solutions for creating permanent solutions. During the interviews, new knowledge acquisition was also identified as an important factor for innovation, but specific examples were not presented or mentioned in this regard.

KM as an Innovation Enabler

Knowledge Management (KM) should ensure that the right information and knowledge are available to the right people at the right time. This is crucial for creating new products and enhancing service provision. Continued education and understanding of processes can drive innovation and efficiency. A comprehensive understanding of processes allows individuals to gather knowledge from various sources, including their own tacit knowledge, to find innovative solutions.

During the interviews, most participants emphasized the importance of tacit knowledge. They suggested that teams should be given space to present innovative ideas and new practices to support people in innovating. It is crucial to provide the opportunity for idea exchange, discussions, and systematic managerial support to bring these fresh ideas to fruition at a center level. All three centers where the interviews were conducted have dedicated innovation teams to handle new ideas and knowledge from operational teams. Additionally, there are global teams responsible for identifying innovative ideas and supporting their implementation. These global teams play a vital role in identifying and diffusing new knowledge among centers in different regions, not limited to CEE, western Europe, or North America.

Furthermore, it was noted that not all knowledge can be documented, and some always remains with the individual. Communication tools such as emails or online meeting rooms can help bring new knowledge to light and share it with other team members. During knowledge sharing, documentation can aid in structuring the collected knowledge and capturing partially applied tacit knowledge. Knowledge Harnessing for Innovation.

People have the ability to innovate and gather complex knowledge from various sources. This collected knowledge, combined with individuals' personal insights, can be used to generate new solutions and knowledge, leading to innovation. People play a vital role in this knowledge processing to develop new products and services. Documenting and structuring ideas supports decision-making for innovation projects. It has been noted that verbal communication alone may not effectively convey technical details, making it necessary to document new solutions in a standardized format.

KM Activities and Processes

During the interviews, KM activities were identified as knowledge creation, validation, presentation, distribution, and application. Another manager used a similar classification, organizing KM into steps: knowledge identification, acquisition, internalization, sharing, and reuse.

We need to identify the scope we will be taking over and understand how we will update and maintain documentation. The next step involves preserving knowledge for reuse and then updating that knowledge. This process can be complex.

Knowledge Resources Management

Respondents had difficulty in identifying what knowledge management (KM) is and how to apply it in strategic planning for the organization. However, during the interviews, they provided numerous examples of KM practices and tools already being used in daily operations. It was possible to map interview findings for KM practices to previous shown KM strategic framework as follows:

- Knowledge strategy as business strategy to provide vision in organizations [17, 18],
- intellectual asset management strategy by retaining people,
- personal knowledge asset responsibility to ensure motivation,
- knowledge creation through dedicating free time for KM activities and
- knowledge transfer within the organization and across other service centers by providing the right communication tools

Furthermore knowledge transfer [19] is a strategic way to ensure knowledge continuity and retention in the organizations. One example is to have assignments in other centers and other regions, facilitating systematic sharing and transfer of knowledge.

The process of knowledge creation starts with capturing knowledge using tools and processes, validating and filtering or structuring the knowledge, and saving it. Once the knowledge is saved in central databases or team rooms, it can be shared with newcomers or distributed globally. To effectively share and distribute knowledge, it should be written down, explicitly explained, or documented. Dedicated teams or process owners are responsible for capturing and processing knowledge. It is important to have structured knowledge available for newcomers to immediately prepare them for their roles and responsibilities by providing them with courses and educational materials.

The dedicated individuals capture knowledge, organize it, and create specific documents and relationships based on it. In project-based knowledge creation activities, a problem is given to a team of experts, who are asked to resolve it in a new environment within a set timeframe. This approach helps teams engage in brainstorming and mind-mapping to identify potential solutions. It motivates and encourages people to use their experience and implicit knowledge to find solutions while also documenting these solutions. Moreover, systematic job rotations are implemented to help individuals learn new knowledge and gain experience in fields related to their core job roles.

Mentors willing to share their experience and knowledge with others are vital in ensuring that knowledge is retained within the organization. Mentors help newcomers adapt to the workplace and their teams by applying their knowledge alongside new employees. Sharing experiences with new employees also supports the continuity of knowledge and helps build trust within the team [20, 21]. In addition, designated individuals or teams within the organization provide education for new employees. These individuals or teams have developed and also handle Knowledge Management (KM) initiatives over time.

You have mentors who are willing to share their experiences. I have several mentors and have had them since the very beginning. In addition to mentoring programs, there are systematic knowledge management practices to identify, collect, save, and document knowledge. This process involves reviewing and updating documented knowledge with new inputs from daily operations. A dedicated team is usually responsible for updating process documentation. Project teams are also in place to handle specific problems, with mentors or senior managers facilitating open space collaboration through face-to-face meetings. This type of interaction helps

teams communicate and share knowledge effectively. Similar project-based teams and global expert teams attend project meetings through online collaboration tools such as conference calls, webinars, or virtual team rooms. This project management approach further facilitates knowledge diffusion and retention across global teams and centers.

In many interviews, it is mentioned that people are crucial for knowledge retention. While explicit knowledge can be retained through documentation, this approach is limited to process manuals and guidelines, which typically only address known issues. Resolving new and unfamiliar problems requires the experiential and tacit knowledge of people. However, this idea was challenged or misinterpreted by a manager who stated that their service center in Slovakia provides employees with good working standards. They are expected to fulfill their duties even under challenging conditions, and if they are not satisfied, they have the option to leave the organization. This statement conflicts with the importance of people's knowledge in knowledge retention.

When hiring people, it's important to clearly communicate their work hours and expectations. If someone decides the job isn't right for them, they should be able to leave. When someone leaves, their experience and knowledge should be passed on to their replacement. It's also helpful to share knowledge with other team members and have a backup person who understands the role. This can ensure that everyone is aware of what others do and can help transfer knowledge when someone is absent. Reviewing any issues that occurred while someone was away can also help in sharing knowledge. Giving people assignments to handle smaller tasks can also help them learn new things and contribute to knowledge sharing across the organization.

Remember to always prioritize knowledge sharing among a group of people. Usually, knowledge is spread across multiple individuals, each with different priorities. We refer to this as the data team matrix. Also, make sure to share knowledge within the team before someone leaves. This is our approach to maintaining knowledge continuity.

The team atmosphere and friendships are crucial for knowledge retention. When someone leaves, they may feel a sense of responsibility toward their teammates and want to share their experience and knowledge before departing. Close relationships help build trust and ensure a smooth handover, even if the knowledgeable person leaves the organization.

Organizations don't have tools to force someone to share their knowledge, so they rely on the person's agreement and willingness to share. Typically, only explicit and documented knowledge is shared, while tacit knowledge remains with the individual. This underscores the importance of retaining people in the organization to ensure knowledge retention.

The complexity levels of a service define the knowledge management practices [22–24]. As the service center ages, the complexity of knowledge increases. Initially, simple and manual tasks are transferred from countries to centers, but over time, the center starts handling more complex tasks. This natural evolution of service characteristics results in the accumulation of organizational knowledge.

There is a problem with conflict and a lack of trust in top management. It seems that fair handling of center performance is not based on knowledge management (KM) activity measurements but on daily business performance [25]. This overlooks the importance of creating new knowledge to stay competitive and the need for KM-based performance indicators to motivate people to be involved in creating new knowledge. Additionally, language skills are considered basic knowledge rather than specialist knowledge. Skills are measured in terms of complexity and cost. In interviews, the evaluation of a person's KM activities was not mentioned, only the development plan for a person to perform tasks better in terms of quality and quantity. Clear knowledge activity-related key performance indicators (KPIs) were not mentioned. There is no answer provided for knowledge-based performance indicators in evaluating a person's value and performance.

3.4 Knowledge Flow Management and Enablers

To promote knowledge sharing, the organization has identified job rotation as a systematic approach. Job rotation aims to provide hands-on experience and learning opportunities by exposing individuals to controlled challenges, enabling them to apply new knowledge to find solutions. It also helps in understanding end-to-end processes and facilitates knowledge sharing. Another method to support hands-on learning is through supervision and delegation. In this approach, complex tasks are delegated to individuals by their line manager or a senior member, who provides assistance if needed. This approach ensures learning and knowledge sharing through controlled risk exposure and observation by a senior team member. Additionally, regular meetings are held to create and share new knowledge, akin to forming communities or groups with like-minded individuals to facilitate knowledge exchange. The ultimate goal is to capture and share knowledge across global centers through projects and formed communities, promoting sharing and reuse of knowledge.

Newcomers are supported by systematic newcomer programs that are backed by central knowledge databases. Additionally, senior team members provide guidance and supervision to newcomers at the outset. Through the assistance and knowledge sharing of experienced senior members, new individuals are able to start at a higher point on the learning curve and become more productive in their roles. This approach also enhances process execution efficiency. Supervisor programs aid in integrating newcomers, reducing their adaptation and transition time. It is recognized that background knowledge has an impact on the learning curve for newcomers.

Knowledge management (KM) [26] requires staying up to date with new changes and information, which is crucial to have the most current knowledge. Keeping knowledge current allows for addressing new challenges with new solutions. Regular education and check-ups are necessary to maintain this current knowledge. In our environment, processes and changes occur frequently.

An open space structure in the centers facilitates face-to-face interactions, enabling the sharing of tacit knowledge through unstructured communication. The

manager's ability to know many people in the center allows for discussions of problems in casual settings, such as the corridor or during coffee breaks in the kitchen, leading to the exchange of ideas and experiences. This open and unstructured communication helps in sharing tacit knowledge, which can support the creation of innovative practices and the use of organizational knowledge. Knowledge Acquisition.

Knowledge brokers and subject matter experts (SMEs) are essential not only during the initial stages but also in established centers to gather knowledge and share it with their teams, as well as within the center and across the region. While explicit knowledge can be transferred through documentation, it's challenging to represent tacit knowledge. This poses a difficulty in handling complex knowledge transfer between teams or centers. On-site experts and mentors facilitate knowledge transfer, as well as through project assignments across regions. Identifying the types of knowledge to be transferred helps in defining the transfer methodologies. Center managers analyze the knowledge at hand to determine the most suitable transfer practices to use.

At the outset, knowledge brokers and translators are tasked with introducing new knowledge to the center, without any personal involvement expected from the team members at the center. However, focal points must be designated to identify and document knowledge, as well as to organize and maintain the preserved knowledge. It is their responsibility to disseminate the organized knowledge throughout the organization.

Workshops and simulations are used within the service centers to facilitate the exchange of tacit and explicit knowledge, as well as managerial skills between new and senior managers. These sessions allow new managers to handle specific situations while being observed by senior managers. Subsequently, the senior managers provide feedback in a controlled environment. These simulations and exercises are designed to measure participants' knowledge and experience levels in order to identify any new knowledge acquisition needs.

Perhaps even for two days, we conducted specific simulations or exercises with a group of 20 people from various locations, including different centers and countries. These activities were observed by experienced senior management.

Face to face and interactive meetings are seen to support knowledge acquisition positively, as people find these type of activities motivate learning. Instant feedback and personal engagement encourages people to find solutions in teams, and also get personal recognition for their actions.

We have webinars and other online education, but face-to-face contact is appreciated more than online education.

A constantly changing environment presents the challenge of acquiring new knowledge to survive. Company acquisitions also occur at the collaborative level in this dynamic environment.

To join the other company as I mentioned, to gain new knowledge and expand our business. We will join with XYZ Company to create a new company with the intention of acquiring proper technology and improving our business position.

The importance of preserving knowledge is recognized through observation and active involvement in creating solutions. Designing a central knowledge center is crucial for identifying and selecting knowledge, as relying solely on documented knowledge is not enough to address all processes and daily challenges. People need the space and opportunity to come together and discuss issues, and personal interactions are crucial for selecting tacit knowledge that can help address observed or shared problems. Once knowledge is identified and selected, it needs to be documented and formalized, and then regularly reviewed to ensure its relevance.

We gather information in a specific knowledge management database [26]. Our colleagues capture this knowledge using a specific format, which we then review and consolidate into a final status report. Personal interactions are also encouraged globally through project teams made up of experts from other centers within the CEE or from other regions of the world. In these teams, members share their experiences and best practices to collaborate on finding solutions to specific problems. Knowledge is shared and reused across global centers through projects and communities. Social internal networks, virtual team rooms, and blogs facilitate online collaboration between remote team members [27, 28]. Blogs also support informal communication between team members and can facilitate personal involvement in finding solutions for problems of personal interest.

We had similar global activities where centers communicated and collaborated due to specific projects, simply sharing best practices.

Information and data can be filtered using metadata, allowing alerts and newsletters to be tagged or summarized to help recipients identify and follow important knowledge and disregard unimportant information.

3.5 Knowledge Transfer Processes.

Knowledge transfer is a continuous communication between involved parties. There are three main stages:—the setup stage, stable state, and supporting new service center establishment in CEE or other regions. Knowledge transfer in stages also includes skills to be learned and transferred.

During the set-up stage, straightforward activities are moved from countries to centers by documenting procedures and processes. At this stage, subject matter experts or knowledge translators were sent to work in the countries to gain hands-on experience and observe the tacit knowledge of country teams. Later, these knowledge experts shared their experiences with the center teams to transfer some of the tacit knowledge from the countries. In some cases, relying solely on documented processes or desk procedure guidance was insufficient.

We had the subject matter experts in Slovakia, and the knowledge transfer was initiated. We have started to offer these courses to people. In the second stage, more and more complex processes and services are transferred to the centers so that, at some stage, the centers have more knowledge and experience than the countries. The same course is seen in all centers; a transition from simple to complex activities,

a rise up the learning curve, and organizational knowledge building is observed. During this stable stage, the centers can fully support the countries in handling complex and exceptional situations. In the current stable stage, with the centers fully responsible for process execution, improvements and standardization. It is possible to see further knowledge transfer taking place, moving the process of knowledge to far-east countries or to South America. During the current stable stage regional knowledge transfer is facilitated through senior manager rotations within the centers, ensuring knowledge transfer not only within the CEE region, but also across the Globe. Established service centers have accumulated complex knowledge which is difficult to transfer to other newly established centers, since documented knowledge transfer is found to be insufficient in both experience and tacit knowledge.

The management of systematic knowledge transfer in both service centers is based on identifying the knowledge. The type of knowledge that needs to be transferred determines the transfer process and documentation required. It has been found that analyzing the country's knowledge and processes beforehand helps in designing the appropriate knowledge transfer methods. The different types of knowledge play a crucial role in making these decisions. An experienced knowledge worker can aid in facilitating the transfer of knowledge to the center by identifying the knowledge types if the knowledge is already documented. The transfer of tacit knowledge, which is knowledge kept within people, has a significant impact on transfer activities and processes. The responsibilities and planning are based on these identifications, followed by the active reuse and application of the transferred knowledge in new teams or a new center. It seems that a combination of documentation-based knowledge transfer and personal interaction is used to bridge the knowledge transfer gaps in tacit and explicit knowledge transfer.

3.6 HR and KM Integration

Knowledge performance-based compensation is not found to be applied in the service centers monitored. Major knowledge activities are not mentioned in measuring individual performance; only some knowledge activities, like organizing meetings or training for the implementation of new processes, are mentioned. It is seen that there is pressure to get the daily tasks accomplished at a given performance benchmark, which is measured with several KPIs based on process speed and efficiency. Personal recognition and social connectivity motivate people to share their knowledge with others and newcomers.

One specific challenge identified in HR management in service centers is how to keep contractor employees motivated, even if they don't receive the benefits that the internal client company offers to its regular employees. People managers find it difficult to encourage all employees, including contractors, as the benefits that motivate regular employees do not apply to contractors or leased employees. Contractors often question why they should perform better when they don't receive the same benefits as regular employees, leading to a challenge for people managers. This challenge affects

employees' motivation in new solutions or knowledge-creation activities, as they are only evaluated based on their performance in terms of cost and time efficiency rather than on their contribution to knowledge and innovation creation. Center managers face the added challenge of aligning themselves for learning and innovation creation activities while delivering services under pressure to be efficient in cost, resources, and service quality. Knowledge Management (KM) motivates people to contribute to knowledge creation and innovation. Individuals can identify with their work and deliver better services and solutions through this involvement. Through knowledge creation and learning, KM can help motivate individuals for personal development. Well-educated individuals are also more willing to learn and acquire new knowledge, making it a good selection criterion, even for a starting position. However, this is a separate discussion and is beyond the scope of this research.

The interview highlighted the significance of trust in various aspects. Participants emphasized the role of trust in building relationships, facilitating communication within teams and with customers, and fostering motivation for knowledge and solution creation. Trust was also seen to promote a sense of unity within teams and shared responsibility and ownership for service quality. Furthermore, trust was found to support innovation activities and the transfer of process and country knowledge to ensure customer service quality. Effective communication between the center and country teams was facilitated by trust and was crucial in finding cooperative solutions. Trust was deemed more important than communication techniques and tools in this regard. Additionally, trust was identified as a key factor in building relationships, facilitating partnerships, and ensuring smooth knowledge transfer even when key personnel leave the organization.

Further, the effect of building trust is seen in the managerial layers, where trust is seen to ease the communication of the strategies and long-term goals of the organization to the whole service center. Uncertainty, resulting from not communicating the vision for the center, can influence the trust between center workers and the main company. Clear communication of strategies can help build trust and let people identify with the company strategy. The importance of trust in motivating people in the company's interest is clearly stated by most of the interview participants. Similarly, communication skills are important in gaining the team's trust for a good people manager.

Team motivation is strong at the center level, but there are clear differences between the parent company and the center management. Building trust between the corporate headquarters and the service center managers could help alleviate uncertainty among the center employees and motivate them to create extra value for the service centers.

To achieve this, I would involve the strategists who create the company's strategy and senior managers and ensure that proper communication reaches all employees. Establishing trust within the company and addressing uncertainties will be key in boosting motivation. Despite the uncertainties, the employees are not leaving the company; they are waiting to see what will happen, and I believe it's because they have strong teams and good relationships that keep them together. Time Dedication for Knowledge Activities.

Many interview participants stated that their operations lack dedicated time for acquiring, creating, and sharing new knowledge. Initially, there was clear time planning and dedication to facilitate knowledge transfer from countries to the center, and a budget was assigned to support knowledge acquisition for the center teams. However, there has been a noticeable change in managerial behavior between the start and the current stable state. Most managers agree that during the center's establishment, there was more time, better-organized education programs, and travel opportunities to the countries. Both country and corporate management communicated with the center management to request time and cost calculations for knowledge acquisition and proper planning. However, in the current stable state, corporate management is asking the center management to take over activities without requesting their feedback or providing the necessary time to absorb the activities. As a result, the center management is struggling to manage knowledge activities, as there are no dedicated resources, especially time, for knowledge management. The center management is left to decide and create time for knowledge management activities and developing new solutions. Many interview participants also expressed their frustration, indicating that without dedicated time, finding new knowledge, generating fresh ideas, or implementing innovative ideas in service operations is almost impossible.

This discovery can help us identify a key issue in center management: most service centers are designed to deliver services in terms of cost and resources efficiently. However, this agile design makes it challenging to engage in innovation activities, as innovation processes are often costly. Even if center management attempts to support new ideas and knowledge generation, it can be difficult to expect groundbreaking innovation from the center teams. Instead, improvements in operational areas are more likely.

Another issue in center design is that the primary motivation behind establishing BPO and service centers is to increase cost, resources, and process standardization efficiency to reduce cycle times. To achieve this, fewer resources and man-hours are allocated to process executions, resulting in overloaded teams handling customer and operational requests with complete dedication. Strategically, BPOs and service centers are not planned to create innovation and new service products but to most effectively support existing processes, which often means fewer resources and less time.

4 Conclusion

Based on the findings and analysis presented in this study, we can draw several important conclusions regarding knowledge management (KM) and competitive advantage in Central and Eastern European (CEE) Business Process Outsourcing (BPO) service centers:

1. The competitive landscape is changing for CEE service centers as they are facing more pressure from low-cost countries. The cost advantage of CEE centers is shrinking because of higher salary levels and standardized processes. This emphasizes the importance for CEE centers to find new sources of competitive advantage beyond just cost efficiency.
2. Knowledge as a Key Differentiator: The accumulation of complex knowledge and expertise has emerged as a critical factor for maintaining competitiveness. CEE centers have developed deep organizational expertise through years of operation, which is difficult to replicate quickly in newly established centers.
3. Innovation Challenges: While innovation is recognized as a sustainable competitive advantage (SCA) source, many centers struggle with implementing effective innovation processes. Lack of dedicated time, resources, and management systems to support experimentation hinder innovation efforts.
4. Knowledge Management Practices: Centers employ various KM practices, including mentoring, job rotation, and dedicated knowledge teams. However, there is often a lack of strategic alignment between KM activities and overall business strategy [29].
5. Human Resource Management: Retaining talented employees is crucial for knowledge retention [30]. However, centers face challenges in motivating and retaining regular and contract employees, particularly regarding knowledge-based activities.
6. Trust and Communication: Trust emerged as a critical factor in facilitating knowledge sharing, innovation, and effective communication within centers and with parent companies. Building trust can help alleviate uncertainties and motivate employees to create extra value.
7. Time Constraints: As centers mature, there is less dedicated time for knowledge acquisition and creation compared to their initial set-up phase. This poses a significant challenge for ongoing learning and innovation.
8. Strategic Positioning: Many CEE centers struggle to clearly articulate their competitive advantage in the global BPO market. There is a need for better strategic positioning and awareness of global competition.
9. Language Skills and Geographical Proximity: These remain important advantages for CEE centers, particularly in serving European markets. However, these advantages alone may not be sufficient for long-term competitiveness.
10. Knowledge Flow Management: Centers have developed sophisticated processes for knowledge transfer and sharing, both within the CEE region and globally. However, transferring tacit knowledge remains a challenge.

CEE BPO service centers face increasing competitive pressures and need to focus on developing robust innovation processes, aligning KM strategies with business strategies, improving retention and motivation strategies for knowledge workers, articulating clearer value propositions beyond cost efficiency, and investing in continuous learning and knowledge creation despite time pressures to maintain and enhance their competitive position.

Future research should explore how CEE centers can better utilize their accumulated knowledge for innovation, develop more effective KM performance metrics, and create strategies to compete against emerging low-cost competitors while maintaining their unique advantages.

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Effective Strategies for Social Media Marketing: A Case Study of Business Promotion

Yuriy Sierov, Ruslan Kravets, Natalia Mykhalchyshyn, Bogdan Mochurad, and Liubov Dymyd

Abstract In the modern world, social media has become a place for communication and a powerful tool for business promotion. This study investigates effective methods and approaches for social media to increase awareness, attract the target audience, and maintain a positive image of the restaurant. The study examined theoretical information about social networks, methods of social media marketing for the restaurant business, and the main tasks of Social Media Marketing. It also analyzed the advantages and disadvantages of using social media in the restaurant industry. The study results showed that Instagram is one of the most effective platforms for promoting restaurants due to its visual nature. Developing a goal tree, information, and functional models during the study has proven to be valuable for planning and executing a promotion strategy on the Instagram platform.

Keywords Social media · Communication · Social networks · Positive image · Restaurant industry · Promotion strategy

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1 Introduction

In the modern world, social media has become a place for communication and a powerful tool for business promotion. They provide unique opportunities to engage the audience and advertise products and services. The topic's relevance is underscored by the growing influence of social media, as social networks have become a powerful tool for communication and influence on society. In recent years, they have significantly increased their popularity and user activity. Using social media to promote a restaurant is an important strategy, allowing you to reach a broad audience and interact with them directly. Another crucial factor is the shift in consumer habits. With the widespread use of mobile devices and Internet access, consumers increasingly turn to social media to search for restaurants, rate their experiences, view menus, and share comments. As a result, restaurants should leverage social media to enhance and maintain their presence in this digital landscape.

The potential benefits of social media for Celentano Pizzeria are significant. In the competitive gastronomy industry, social media offers a unique opportunity for restaurants to differentiate themselves. It enables Celentano to cultivate a strong brand, engage with its customers, share current information, and attract more customers. This study aims to explore these benefits in detail, providing a roadmap for Celentano and other restaurants to leverage social media effectively.

This study is of utmost importance as it investigates effective methods and approaches for social media to increase awareness, attract the target audience, and maintain a positive image of Celentano restaurant. The main tasks of this study include:

Analyzing current trends in the use of social media by restaurants and their impact on successful brand promotion:

- Reviewing the principles of creating and managing a restaurant's social media profile.
- Exploring the role of visual content (photos, videos) in attracting attention and creating an aesthetically pleasing profile.
- Studying the regulations related to the restaurant business.
- Analyzing the impact of social media on the reputation of Celentano restaurant.
- Assessing the results of using social media by Celentano restaurant, including audience engagement, interaction, and the impact on the restaurant's popularity.
- Developing recommendations to improve the effectiveness of information and advertising support for promoting Celentano restaurant on social media.

2 Analytical Review of the Literature

With the development of the Internet, restaurants have seen their advertising campaigns shift from traditional advertising, such as newspapers and brochures, to online marketing. One of the first articles dedicated to restaurant marketing on the

Internet was that online marketing would become a necessity rather than an option [1]. Websites help increase restaurant awareness as consumers search for information online, but websites are one-way communication. Because of this limitation, restaurants are adding social media marketing, which is more interactive than websites [2].

Social media is not a new concept but a new form of interaction with people. A Gallup poll found that 72% of adults use social media frequently during the day. Social media's impact has changed how businesses relate to customers [3].

Businesses utilize social media to cultivate customer relationships and connect with new prospects [4]. Some consumers seek specific information about products and services, while others use social media to offer valuable advice, share experiences, and exchange information globally [5, 6]. Social media platforms allow companies to engage with current and potential customers, fostering exceptional relationships. Business leaders leverage social media to interact with and influence customers, driving sales and increasing brand awareness [7].

Social media is a dynamic process in any business [8, 9]. It is a tool and a strategy that requires commitment and constant monitoring across the organization [3]. The biggest challenge for companies in social media marketing is determining how and when to use it appropriately and effectively. The European studies in [10] showed that a restaurant's effectiveness increases with positive online customer reviews.

Restaurants that utilize social media can build trust with their customers by fostering relationships and enabling patrons to share their dining experiences with others. Customers' feedback, recommendations, and comments about the services offered, along with photos, are not just shared but valued. This allows restaurants to pinpoint their target audience and deliver more tailored information to consumers [11].

Given the pandemic and the current global situation [12], our top priority should be taking care of our health and the health of our loved ones. Many companies, including those in the restaurant business, prioritize safe consumption and maximum benefit for their guests. In this context, restaurateurs should pay close attention to online marketing tools, particularly social media. This involves not just using but actively promoting the restaurant business and its brand through social media content created or updated by owners and visitors, mainly through social media marketing. This active role in promoting their business empowers restaurateurs and puts them in control of their marketing strategies [13]. Effective SMM is essential in successfully promoting a brand, product, or company in the market. It aims to attract more fans, expand the target audience, and develop, improve, and protect the company's reputation by building customer loyalty. SMM is social media marketing, which consists of activities on other people's platforms (forums, blogs, websites, chat rooms, news resources) to promote goods and services. Such influence is not open advertising. Hidden, unobtrusive advertising draws the target audience's attention to the product. Users should never realize that they are being forced to buy a product. Social media users should want to buy a product or service because of the information provided. Moreover, information about the promoted product is offered to the target audience

through feedback, communication between users, and exchange of opinions [14]. The main objectives of SMM are:

- Social networks can quickly drive traffic to your website or business page by helping you attract a new audience. You can achieve this by recruiting your target audience from relevant groups and redirecting them to your page. Social networks also offer opportunities to set up an offline sales system. You can sell goods directly from your page, as social media pages have a familiar and user-friendly interface.
- Increase brand awareness by strategically distributing advertisements and incentivizing users to spread the word.
- Organizing the flow of loyal users involves utilizing social networks to build a database of regular users who can be informed about the company's offers through personal pages or groups. Running promotions and contests to attract and maintain potential customers is also advisable.
- Counteracting negativity is one of the top priorities of SMM. Group administrators must respond promptly to negative feedback from users and handle the issue with loyalty to maintain a positive perception of the company among other consumers.

Since organizations optimize their costs, building a brand through social media is very effective. In addition, it is much easier to segment consumers and target advertising in SMM than in traditional media: firstly, it allows you to reach more target consumers, and secondly, it allows you to bring them to the page immediately at the lowest advertising cost (the cost per customer through SMM is lower than through contextual advertising). It's also worth noting that over the past few years, there has been a shift from text-based social media marketing to photo-rich social media marketing [15]. Studies show that photos and videos help to attract customers' attention to purchase [16, 17]. Photos in food blogs and restaurant advertising, for example, help tourists experience sensory appeal, creating a psychological impression and inspiring them to plan a visit to a restaurant [18].

Social networks [19–21] have long been an integral part of modern life. For some people, pages on one social network or another have acquired commercial value and become a tool for making a profit. Therefore, it is important to understand that laws and regulations play an important role in the restaurant business, especially regarding its presence on social media. The following aspects demonstrate the importance of laws for the restaurant business on social media:

The official language in Ukraine is Ukrainian, as stated in the Law of Ukraine "On Ensuring the Functioning of the Ukrainian Language as the State Language" [22]. This Law requires that all services, whether online or offline, be provided in Ukrainian.

The Law of Ukraine, "On Personal Data Protection" [23], characterizes confidentiality and data protection. The Law establishes requirements for collecting, storing, and using social media users' data. Restaurants must comply with these rules when they collect information about their customers or access personal data through social media.

Restaurants can utilize social media to promote their services, attract new customers, and maintain relationships with existing ones. In Ukraine, the "Law on

Advertising" [24] governs advertising and marketing practices, including regulations on deceptive advertising, competing brands, and the unauthorized use of images and content. Ukraine's "Law on Copyright and Related Rights" [25] governs this. Posting images, texts, or videos on social media involves copyright and intellectual property rights. Restaurants must adhere to the laws concerning the use of content owned by other authors and obtain permissions or licenses to use images or materials if required.

Social media platforms allow customers to leave comments and ratings about restaurants. Restaurants need to monitor these comments and ratings closely. In Ukraine, the Law "On Information" [26] may apply to comments that damage the restaurant's reputation or violate customer privacy. Regulation of Alcohol and Tobacco Promotion: Many restaurants utilize social media to promote their alcoholic beverages. However, the Law "On State Regulation of Production and Circulation of Ethyl Alcohol, Cognac and Fruit Alcohol, Alcoholic Beverages, Tobacco Products, Liquids Used in Electronic Cigarettes and Fuel" [27] in Ukraine restricts the promotion of alcohol and tobacco, especially among minors. Therefore, restaurants should consider these regulations and adhere to the relevant rules when publishing alcohol or tobacco advertising.

Competition laws. Social media allows restaurants to promote themselves and interact with consumers. However, the Law of Ukraine, "On Protection against Unfair Competition" [28], sets out rules regarding unfair competition, including defamation, copyright infringement, or illegal use of patented technologies. Restaurants must comply with these rules to avoid legal problems.

Protection of consumer rights. The Law of Ukraine, "On Protection of Consumer Rights" [29], characterized this. The Law is essential for commercial social networks because it establishes consumers' rights and obligations, including the right to information about goods and services offered on social networks, requirements for the quality of goods, and return policies.

Cybercrime. Along with the growing use of social media, new threats and risks associated with cybercrime have emerged, regulated by the Convention on Cybercrime [30]. Cybercrime legislation may establish rules to limit negative comments, threats, and other negative impacts on the community. The Law combating cybercrime on social media promotes cybersecurity and sets out information security requirements that restaurants must meet. Overall, the Law combating cybercrime on social media is important for ensuring online restaurant business security, reputation, and privacy. It helps build consumer trust and ensure a successful social media presence.

Compliance with the Law is essential for the restaurant business on social media [31]. It helps restaurants maintain their reputation, prevent legal issues, and ensure the safety of customers and employees. Compliance with the Law also helps build customer trust and increases their confidence that the restaurant follows ethical and legal guidelines. In addition, non-compliance with the Law can have severe consequences for a restaurant. This can lead to customer complaints, fines, lawsuits, reputation loss, and business loss. Therefore, it is crucial that restaurants thoroughly

research and understand the laws that govern their social media activities and comply with all requirements.

In light of social media's growing impact on society, restaurant owners must stay updated about any legal changes in this sphere. Adhering to laws and ethical norms is essential for the success of restaurants' social media presence.

The chapter reviews theoretical information on restaurant promotion through social media (SMM). It studies the concepts of social networks and SMM and analyses the main tasks of SMM. This section also discusses the advantages and disadvantages of SMM in the restaurant business.

The section also provides an overview of the laws and regulations that apply to the restaurant business on social media.

Printed advertising includes creating and distributing advertising materials such as posters, brochures, leaflets, and other printed materials. These materials contain information about new dishes, special offers, promotions, and other novelties related to the restaurant.

Print advertising has a significant impact on the success of the restaurant business. First and foremost, the benefits of print advertising include attracting new customers. Advertising brochures, flyers, posters, and leaflets attract the attention of potential customers, as the restaurant is located where many people pass by, so print advertising helps attract new visitors. Such advertising also allows you to showcase your menu and special offers. It is worth posting photos of the dishes and describing them to interest people and make them want to try the restaurant's cuisine.

Print advertising is also an effective complement to other forms of advertising, such as social media. It allows us to deliver our message to an audience that is not active on the Internet or social media. However, we should not forget branded elements equally crucial in promoting a restaurant.

Branded clothing. Restaurant employees wearing clothes with the company's logo become living advertising messages. This raises brand awareness among visitors, especially as employees (pizza makers, waiters) interact with guests because they are in visible places. Branded advertising on clothing and other materials helps spread the word about the restaurant to different groups of people. When employees wear clothes with the logo, it arouses interest among people who could become our customers. When consumers see employees wearing the logo, they associate it with professionalism, reliability, and quality of service.

Branded packaging. The restaurant offers a takeaway service, so branded packaging is an effective way of advertising. The restaurant logo or brand elements on the packaging attract attention and leave a positive impression on customers, helping to create a single and coherent brand identity.

A menu is more than just a practical item in a restaurant—it also plays a crucial role in reinforcing its brand identity. Additionally, providing branded items like balloons as small gifts for our customers' children can leave a positive impression and help increase customer loyalty. When people receive these branded gifts, they may place them in their homes, constantly reminding them of the restaurant and encouraging repeat visits. These elements complement the overall restaurant advertising strategy and have the following advantages:

- building trust;
- maintaining customer loyalty;
- a reflection of professionalism and quality;
- creating an emotional connection;
- raising awareness of the restaurant;
- strengthening the competitive advantage;
- creating an impression of high quality;
- attracting new customers;
- Increasing the perception of value;
- support for repeat visits;
- strengthening brand identity.

The restaurant business is subject to various regulations and rules, including local, regional, and national legal requirements. Knowing these requirements helps restaurateurs comply with legal restrictions and avoid possible sanctions or fines.

One of the most important documents related to a restaurant is the sanitary norms and rules. This regulatory document sets out the requirements for the sanitary condition of catering establishments and the quality and safety of food products. This document specifies requirements for the location of establishments, equipment, storage and cooking conditions, waste management rules, etc. Another regulatory document is the internal regulations. This document contains rules that establish the procedure for the operation of the establishment, rules for customer service, working conditions of employees, requirements for the appearance of staff, compliance with etiquette, and other issues related to the internal life of the restaurant.

The restaurant menu serves as an essential document. It is a crucial reflection of the range of dishes and drinks, their prices, and information about the ingredients. Beyond just a list of offerings, the menu is a marketing tool to attract and retain customers. There are several key reasons why the menu holds such significance. Not only does it serve as a means of identification and branding, reflecting the character and style of the restaurant, but it also helps create a unique image of the establishment in customers' minds. The fonts, colors, design, and overall appearance of the menu should align with the concept and atmosphere of the restaurant. Additionally, the menu plays a vital role in increasing sales. Furthermore, a customer contract is a document that outlines the mutual rights and obligations between the restaurant and the customer, including payment terms and establishment rules.

This regulatory document establishes rules and procedures to ensure the safety and health of restaurant staff and guests. It includes requirements for medical examinations, rules for compliance with hygiene standards, emergency procedures, and other health and safety aspects. This document describes the restaurant's quality management system, including product quality control procedures, customer satisfaction assessment processes, improvement plans, and service quality standards.

This document sets out the requirements for fire safety equipment, evacuation plans, procedures, and staff fire safety training. It also includes requirements for the inspection and maintenance of fire protection systems.

Labor protection rules. This document contains requirements to ensure safe working conditions for all restaurant staff. It defines the rules for using equipment, injury prevention procedures, and instructions for performing work safely. The institution was analyzed, considering the founding of Celentano restaurant, its mission, values, and uniqueness. It also investigated what methods Celentano uses to promote itself. It was found that print advertising can be effective in certain situations and can be combined with other marketing efforts. Other advertising channels, such as social media or other innovative approaches, should be improved to promote the restaurant fully.

In summary, advertising in the modern world is quickly evolving. More and more companies are transitioning to digital formats and interactive solutions. Utilizing social media for promotion allows you to gather data about the target audience, analyze it, and tailor advertising strategies to meet specific needs and previous customer responses. A successful advertising campaign necessitates an integrated approach, combining various channels and continuously monitoring results. Adapting to changes in the media and advertising landscape is crucial today, as it requires introducing new ideas and innovations to promote a restaurant effectively.

Additionally, we examined the institution's regulatory documents, highlighting the importance of understanding restaurant business regulations for successful restaurant operations.

3 Methodology

Creating a goal tree is a fundamental step in the information and advertising support of restaurant promotion. This tool plays a crucial role in structuring and defining specific goals in restaurant promotion. Built a tree of goals to solve the problems of the subject area of work (Fig. 1). Identified the means to achieve the goals.

First, we formulated the main objective: "Information and advertising support for promoting Celentano pizzeria on the Instagram social network." Then, she divided the main goal into four sub-goals: company analysis, content distribution, competitor content analysis, and results analysis.

Analysis of the company. To analyze a company, you need to examine its comprehensive image code, and the documents and information on its website will serve as the means to achieve this goal. Next, you should explore the area of activity, which will be supported by documents describing the brand's policy. It is also worth investigating the corporate culture, and the corporate culture code will serve as a tool for implementation.

Content distribution. First, to distribute content, you must create a content plan, analyze the target audience, choose a platform, and create content. To make a content plan, you need to determine the main goals of the page, and the restaurant's profit statistics will serve as a tool for deciding them. You also need to define the types of content, which can be done by classifying the types of content. To create a content plan, you also need to determine the format of posts for the page.

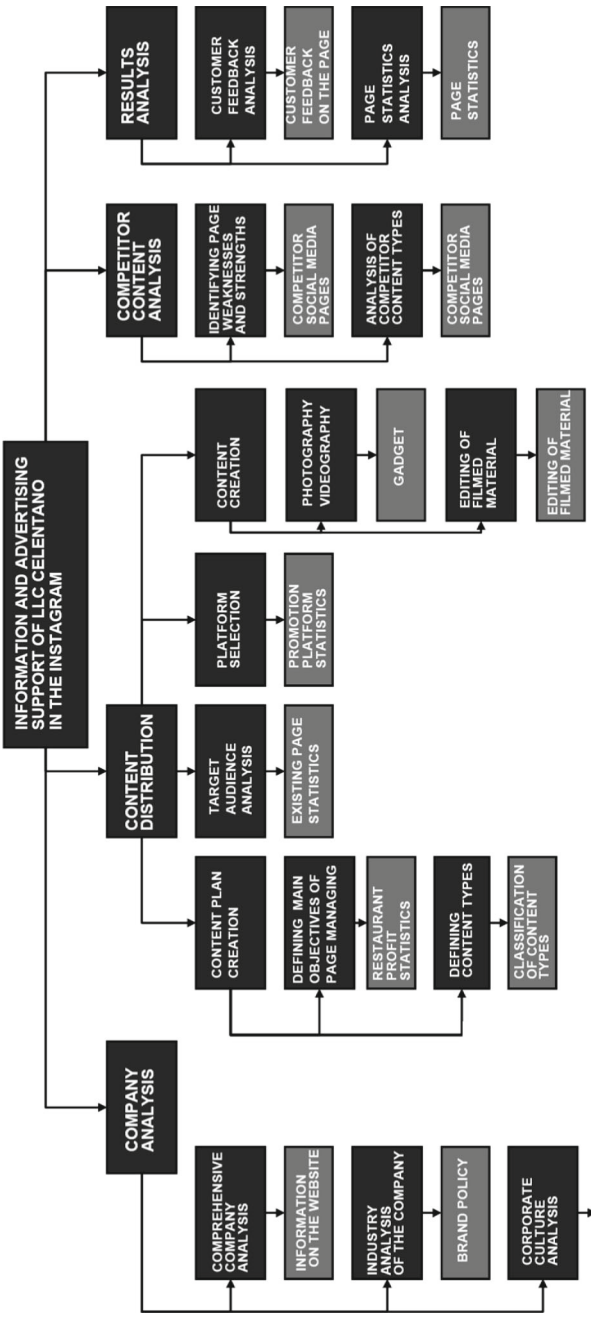

Fig. 1 Tree of goals

The means for determining this will be the statistics of post formats for better promotion. To create a content plan, you will need to choose the frequency of posting, which can be done by using reader activity statistics.

Gain confidence in your content distribution strategy by leveraging the power of existing page statistics to understand your target audience. This data will guide you in choosing the right platform for content promotion, ensuring your content reaches the right people.

To distribute content, you need to create it. Our content creators play a crucial role in this process. To create content, you need to take photos and videos, and the gadget that will be used to make the content is the tool. In addition, to create content, you need to edit the footage, and editing applications are the tools of choice.

Analysis of competitors' content. To analyze competitors, you need to identify their weaknesses and strengths; competitors' social media pages are an excellent way to do this. To analyze competitors' content, you must also determine the content type they publish. The means for determining this will be the competitors' social media pages.

Analysis of results. To analyze the results, it is worth analyzing customer feedback; the means of analysis is customer feedback in the form of responses to our Stories and marks of the establishment in the customer Stories. Customer feedback is crucial to this process, and we value their opinions. To analyze the results, you should also analyze the statistics, which can be found in the statistics on the page.

Developed an information model. We chose the Crow's Foot notation, in which entities are represented as a rectangle with the entity name in the header and a list of attributes in the footer. It was determined that the entities of my subject area are:

- employees;
- clients;
- content.
- Analyzed the relationships between entities and identified the types of relationships:
- A many-to-many relationship exists between the customer and content entities, as one customer can interact with many posts, and many customers can interact with one post.
- a many-to-many relationship exists between the employees and content entities, as one employee can participate in many posts, and several employees can participate in one post.

An ER diagram in Barker's notation was also constructed (Fig. 2). The developed information model was analyzed and described.

The Customer entity contains the following attributes: customer code (key attribute), full name, page nickname, date of birth, place of residence, and marital status. These attributes are included in the entity because they will help to popularize the page on social media. First of all, we need the client's code, full name, and nickname to identify the client, and we also need to know the client's date of birth so that we can offer a promotion or discount on the client's birthday in the future. The customer's place of residence will help you understand where they live and help you

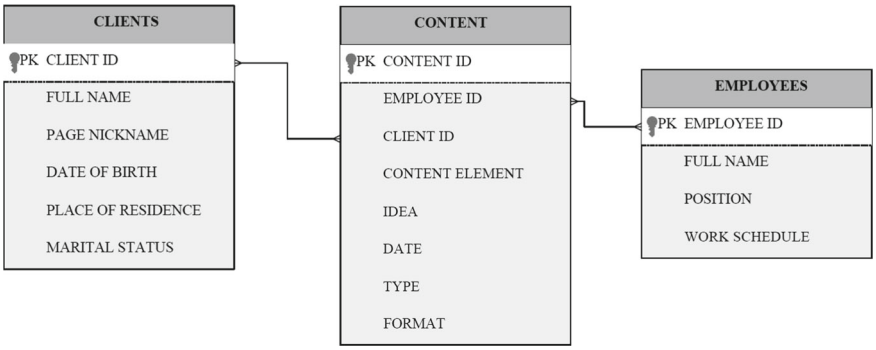

Fig. 2 Information model

offer promotions in the form of fast delivery. The marital status of customers will help you know how many of your audience have children to inform them about the availability of a children's area in the venue or a master class for children.

The Content entity contains the following attributes: content code (key attribute), employee code, client code, content element, idea, date, type, and format. These attributes will help to popularize a page on social media. The key attribute, namely the content code, will help you identify the post that will be published. The employee code will help to understand which post will involve an institution's employee. The client code is needed for the client to interact with the content. The content element will help you understand what will be filmed on that day (bar, kitchen, pizza, restaurant, etc.). The idea attribute will help you briefly describe the shooting scenario to create a detailed shooting plan in the future. The date attribute indicates the date of the shooting. The type attribute indicates whether the content will be entertaining or informative. The format attribute indicates whether it is a photo or video.

The Employee entity contains the following attributes: employee code (key attribute), full name, position, and work schedule. The employee code and full name are used to identify the employee. The position attribute will help you determine what position the employee who will be involved in the shooting holds. The work schedule attribute will help you determine which days the employees involved in the shooting will be at work.

We created a functional model developed in Jordan's notation. It was determined that the primary process of my subject area is the content of a page on social networks. External entities that influence this process are identified: customers, employees, directors, and content makers. The data flows, i.e., the information necessary for the proper functioning of this process and the information that will result from its implementation, are analyzed.

We also constructed a contextual diagram and the first level of detail in Jordan's notation (Figs. 3 and 4).

Although print advertising is essential for the restaurant business, more is needed to promote a restaurant fully. First of all, the audience reach is limited compared to

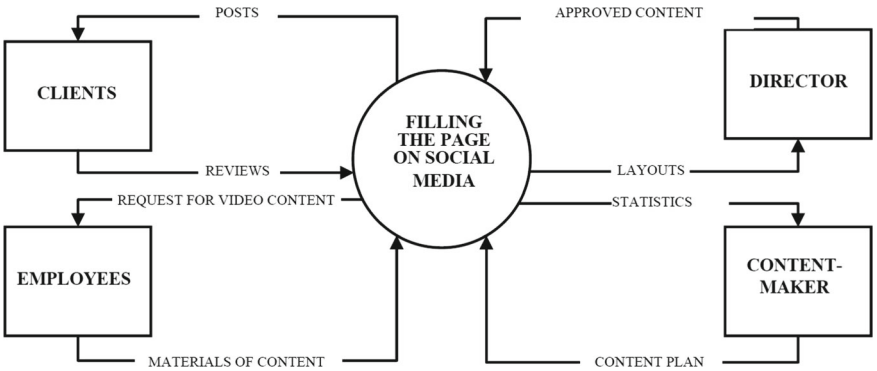

Fig. 3 Context diagram in Jordan notation

social media. Most young people and tech-savvy audiences actively use social media to search for restaurants. Most printed materials are quickly thrown away, as many people skim through printed advertising materials and pay little attention to them, making it difficult to achieve the effectiveness of print advertising. Another negative aspect is the high cost of print advertising. Producing brochures, posters, or leaflets is quite costly for businesses compared to social media advertising, which is more affordable and flexible in budget.

Print advertising typically does not offer opportunities to engage with potential customers, which is essential for promoting a restaurant. On social media, however, you can include a link to the restaurant's location and provide various options, such as placing an order online, leaving a review, or booking a table. This creates opportunities to interact with potential customers and increases the likelihood of converting them into actual visitors.

Promoting a restaurant on social media has the advantage of easily measuring its effectiveness. Data on the number of views, clicks, and conversions can be readily obtained, allowing for a thorough assessment of the advertising campaign's impact. In contrast, it's nearly impossible to control this aspect in print advertising. After evaluating various methods of restaurant promotion, it's evident that having a social media presence is the most effective approach.

However, it is essential to understand which social media platform to choose for the most effective promotion of Celentano restaurant.

To promote Celentano restaurant, you should consider several social networks, each with advantages and disadvantages.

Instagram—Advantages:

- Instagram allows you to attract attention with visual content, such as photos and videos of dishes, restaurant interiors and atmosphere;
- Instagram has billions of active users, including young people and a target audience interested in gastronomy and restaurants;

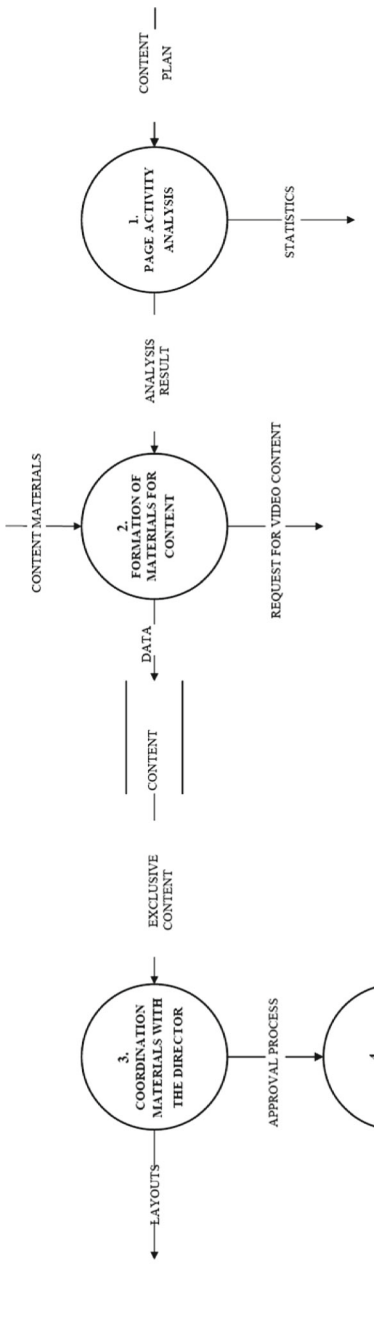

Fig. 4 The first level of detail of the primary process

- Instagram allows you to engage customers through comments, messages, stories, and contests.

Instagram—Disadvantages:

- Due to the popularity of Instagram in the restaurant industry, competition for users' attention is very high, so you need to create high-quality and unique content to stand out;
- If a restaurant doesn't have a lot of attractive photos, it's challenging to attract the attention of Instagram users.

Facebook—Benefits:

- Facebook has the most extensive active user base among social networks, which allows it to reach a wide range of potential customers;
- Facebook provides a variety of tools, such as pages, groups, events, and advertising campaigns, to effectively promote your restaurant;
- the ability to establish contact with your customers, respond to comments and feedback, and conduct surveys and contests.

Facebook—Disadvantages:

- The organic reach of Facebook posts is declining, so you may need to invest in advertising to reach a larger audience;
- The younger generation is less active on Facebook, so this social network may be less effective for the target audience of younger age groups.

TikTok—Advantages:

- TikTok is popular among young people, especially teenagers, so this platform can help attract the attention of a younger audience to a restaurant.
- Thanks to short and engaging videos, TikTok has the potential to go viral and attract a wide audience.
- Collaboration with influencers and popular TikTok users can help attract new customers to your restaurant.

TikTok—Disadvantages:

- the length of videos on TikTok is limited, which can be a challenge for creating full-fledged content about a restaurant;
- TikTok may be more prevalent in some regions and less so in others, so the effectiveness of this platform is reduced.

Considering the audience, visual content, and opportunities for interaction with the community, Instagram remains one of the most effective social media platforms for restaurant promotion. Its active audience, focus on visual content, and advertising opportunities make it an attractive tool for promoting the restaurant business.

A set of goals for information and advertising support for promoting Celentano Pizzeria on Instagram's social network was developed. Information and functional models have also been developed. The advantages and disadvantages of platforms for

information and advertising support for promoting Celentano pizzeria are analyzed. A platform for popularizing the restaurant has been selected. Throughout the analysis, it becomes clear that Instagram is the best suited for this task. After all, Instagram is a well-known platform for displaying visual content.

4 Results

You should first analyze the brand policy to promote Celentano restaurant on Instagram. A restaurant's brand policy is critical in successfully promoting and establishing a solid identity. It defines the values, mission, vision, and core principles on which the restaurant is based and is the basis for all marketing and communication efforts.

Having explored the key aspects of the brand policy during the work, the next step is identifying effective social media marketing methods that can help attract new customers, retain existing customers, and raise awareness of Celentano.

Based on the information studied, Table 1 identifies and presents the SMM methods that are most effective for restaurant business enterprises.

Table 1 SMM methods for the restaurant business

Method of promotion	Specifics
Create engaging content	Posting photos of dishes, beautiful videos, recipes, success stories, nutritional tips, etc. The content should reflect the uniqueness, style, and quality of service
Use of hashtags	Add relevant hashtags to your posts about food, gastronomy, local attractions, and other relevant topics. This will help attract the attention of a new audience interested in such topics
Placing shares and special offers	Attract customers by posting special offers, discounts, promotions, and contests on social media
Engaging users in dialogue	The process of interacting with your subscribers. Asking about their preferences and collecting their feedback and suggestions. Conduct surveys or create challenges to interact with your audience. Responding to comments and messages, providing a personal approach to each client
Cooperation with influential personalities	Collaboration with influencers, bloggers, or journalists with a large audience and interest in gastronomy. Offer a free lunch or a special offer at the restaurant for a review or mention of the establishment on their social media
Holding online competitions	Organise contests with prizes that encourage audience participation. This will help attract new customers and create a positive venue image

Having identified effective methods of social media marketing, we chose those that are most suitable at this stage for the process of promoting Celentano restaurant, namely:

- creating attractive content;
- use of hashtags;
- placement of shares and special offers;
- engaging users in a dialogue.

It's also worth doing a social media analysis of Celentano's competitors, as this can help you understand their marketing strategy and ways to attract customers and interact with them.

The analysis shows that Celentano restaurant's main competitor is Emily Brooklyn Pizza. To promote itself, the competitor cooperates with bloggers. Bloggers often create interesting and attractive content, such as photos and videos, that makes people want to try the dishes and visit the restaurant. This can encourage new customers to visit the establishment and help promote it through social media.

That's why it's essential to cooperate with influencers in the future to promote the project more effectively. After reviewing the statistics, it becomes clear that the page does not publish Stories and rarely publishes posts. This suggests that no one is engaged with the page, which is a big business mistake.

A content plan is an effective strategy for promoting a restaurant on social media. Therefore, the next step is to develop it.

First and foremost, a content plan helps you strategically plan your communication efforts. It allows you to prepare content in advance, allowing you to be systematic and consistent in your publications. It will also help you consider special events, holidays, or promotions that should be reflected in your content. A content plan also enables you to distribute different types of content on other days. It helps you maintain constant activity on your Instagram page. Regular posts help keep followers engaged and stimulate interaction.

A content plan is essential for ensuring consistency, variety, and activity on a restaurant's Instagram page. It helps attract the audience's attention and interest, attract new customers, and retain existing ones.

The next step is to change the restaurant's logo. As the page was promoted during the full-scale invasion of Russia, Celentano changed the logo. A restaurant's logo is an extremely important element for social media promotion. It reflects the restaurant's brand identity and is a visual symbol that is perceived by the audience and associated with the brand.

The next step to change is the profile header of the Celentano page, as it is the first impression of profile visitors. The profile header is a space for an expressive and attractive image that immediately attracts users. It reflects the atmosphere and style of the restaurant. It allows potential customers to immediately get basic information about the business, which can be useful for deciding whether to visit the restaurant. It also helps build brand awareness.

It is essential to pay due attention to the Instagram profile header, as it can significantly impact brand perception, attract new customers, and create a positive impression of the restaurant.

It is also worth paying due attention to favorite Stories. Selected Stories on a restaurant's Instagram page are crucial for attracting the audience's attention and promoting the brand. Since Celentano restaurant does not have an electronic menu, it is appropriate to show various menu items in the selected Stories.

In addition to a variety of dishes, the selected Stories should highlight a category dedicated to the restaurant's customers, and it is worth highlighting with a red heart to show how much the restaurant appreciates its guests.

You should also show a children's area in your Stories, a significant advantage over other establishments. It's also a good idea to show the establishment's atmosphere in your Stories, which will help potential customers understand what the place looks like and whether it appeals to them.

Once the above points have been established, shooting dishes according to a pre-created content plan occurs. Before the shooting process, you should take care of the lighting. It is best to shoot in sunlight. To shoot a video, you need a Celentano restaurant employee to prepare the dish first. Once the dish is ready, the video is filmed.

After that, you need to move on to mounting the rollers. First of all, it's essential to edit the video well. You should also choose popular music when it comes to Reels. After all, this is how its algorithms work.

To publish a video to Reels, you should follow these steps. First of all, select the video you want and add tags. In this post, we used the home page tag of the entire Celentano restaurant chain and the Victoria Gardens Lviv tag. By using tags, there is a high probability that the pages will share the post, which will serve to promote the restaurant further. It is also worth choosing a good cover for the post, as visual content is one of the first things users see when they visit the page. If the photos and videos are well-shot and attractive, they create a positive impression of the restaurant.

You should also add a description of the dish. A well-described and catchy description of the food will provoke a trip to the restaurant. Instagram has the option to add themes, and with this feature, you can choose several themes to help your Reels video find its audience.

It is also worth marking the restaurant's location, as this mark allows users to quickly find the restaurant on the map and find out exactly where it is. This is especially important for locals and tourists looking for places to eat and have a good time in a particular neighborhood or city.

Another essential tool for promoting a restaurant is Stories, which allow you to tell exciting stories about the restaurant, its philosophy, team, and culture. A place where you can show the brand's personality and connect with the audience. Stories help create a more profound perception and engage people who share your values. They offer a variety of interactive features such as polls, Q&As, voting, etc. This encourages active audience participation and creates opportunities for interaction with the restaurant. With Stories, you can ask followers for their preferences and

recommendations or invite them to participate in a contest or promotion. They only live for 24 h, which allows you to capture the restaurant's instant moments.

That's why you should share photos and videos of cooking and showcase seasonal menus, new dishes, or special offers in Stories.

Stories are an excellent tool for showcasing promotions. Posting information about limited-time offers is also a good idea, creating a sense of urgency and increasing the impulse to visit the establishment. Since the restaurant is aimed at a broad audience, with a special focus on family holidays, it is worth showing that it is conducive to such a holiday. It is important for customers to feel that their presence is essential. It is also worth showing that the restaurant is happy to be visited by customers' pets.

The first step in publishing stories is choosing a video. A caption is mandatory, as it will be useful for audiences with hearing or visual impairments. The caption will provide additional context and understanding of the content of Stories for special people. You also need to choose a font. Leaving a survey or sticker is a good idea to get feedback from your followers.

Remember entertaining Stories. They add fun and entertainment to a restaurant's atmosphere and create a unique experience for guests, which helps to make your restaurant stand out from the competition and attract new customers.

Analysis of the Results

As a result of the work, photos, Reels, and Stories were published on Celentano's Instagram page. Before the promotion, the page had 229 followers (Fig. 5). During the promotion period, the Celentano page had 376 followers (Fig. 6). At the end, 147 readers were added.

Before the promotion process, an important step was to change the page's main photo. As mentioned earlier, the Celentano restaurant chain was forced to change its logo, so changing the primary image was a logical decision.

In addition, the profile header was filled with basic information about the institution, as the previous version was not informative.

Since there is no electronic menu, all items were covered in the selected Stories, which, unfortunately, were not shown before the promotion process. Previously, the number of favorite Stories was in two categories. Now, the number of favorite Stories includes 14 categories.

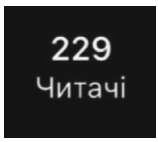

Fig. 5 Number of readers before the promotion process

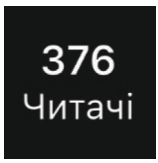

Fig. 6 The number of readers after the popularization process

The design of Stories was changed entirely to make users want to subscribe and follow the establishment's life. Previously, Stories used an outdated and colorful font. Now, Stories look attractive and up-to-date. If you follow all the rules for running Stories, you can observe users' interaction with the page. This can be seen primarily by clicking on stickers and responding to Stories.

To understand users' activity, you should review the statistics. You can see that Stories used to have a shallow reach, but now the reach has increased significantly.

Before the promotion, the Celentano page feed didn't look attractive because it was shot in poor lighting conditions. Now, all the posts are bright and harmoniously combined. Looking at the statistics of posts before and after the promotion process, posts now receive comments and are included in recommendations. The number of views, likes, comments, shares, and saves has increased dramatically.

During the process of promoting the Celentano Instagram page, 14 posts were published, 8 of which were Reels, 6 in the format of photos, and 161 Stories (Fig. 7).

It is worth mentioning that photos and videos in the profile are arranged in such a way as to create a harmonious composition and attract users. Once on the restaurant's page with visually beautiful content, the user will stay, subscribe, and visit the establishment in the future.

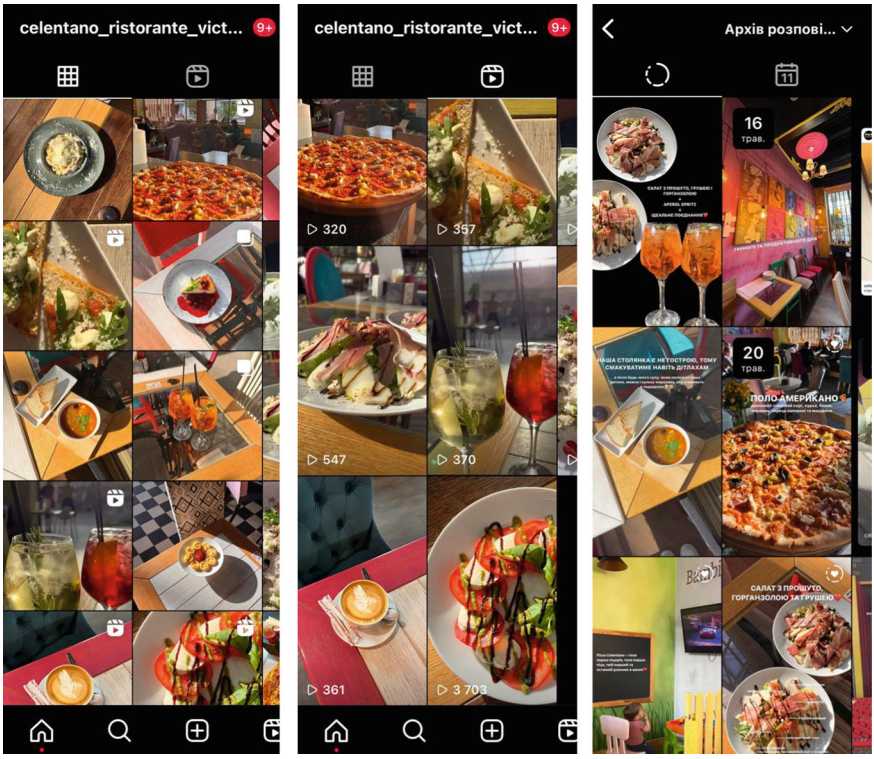

Fig. 7 Published posts, reels and stories

The article describes the process of maintaining Celentano's Instagram page for its popularization. It became clear that by following all of the above means of promotion, the restaurant will receive an increase in subscribers and user interaction with the created content, turning them into potential customers of Celentano restaurant in the future. It also analyses the results of the promotion process and presents the page statistics in screenshot format.

5 Conclusions

The study of restaurant's promotion using the social network Instagram proved to be an important and useful step in understanding effective methods and approaches to attracting the target audience, maintaining a positive image, and increasing the restaurant's awareness. The study's results emphasize the role of Instagram as one of the most effective platforms for restaurant promotion due to its visually-oriented nature. The study examined theoretical information about social networks, methods of social media marketing for the restaurant business, and the main tasks of SMM. It also analyzed the advantages and disadvantages of social media in the restaurant business.

The study results showed that Instagram is one of the most effective platforms for promoting Celentano restaurants due to its visual nature.

It became clear that the successful promotion of Celentano restaurant on social media requires a comprehensive approach, a combination of different communication channels, and constant monitoring of the results. Using various content (photos, Reels, Stories) is recommended. Active interaction with subscribers, responding to comments and messages, and creating attractive promotions and offers will help attract and retain users' attention.

However, effectively managing negative feedback and maintaining a positive image of Celentano is equally important. Responding to customer feedback with attention to their concerns and requests, resolving issues quickly and politely, and actively communicating with the audience help to maintain trust and support a positive perception of the restaurant.

Studying the laws and regulations that pertain to the restaurant industry on social media is an important research step. Understanding these rules will help prevent legal issues and ensure compliance with the law when utilizing social media for restaurant promotion. Developing a goal tree, information, and functional models during the study has proven to be a valuable tool for planning and executing a promotion strategy on the Instagram platform. These tools help identify specific goals, strategies, and tactics that contribute to the success of restaurant promotion. It is worth noting that social media, particularly Instagram, is an effective tool for increasing awareness, attracting the target audience, and maintaining a positive image of Celentano. It is important to use diverse and attractive content, actively engage with the audience, and comply with legal requirements and regulations. Continuous improvement of

strategies and monitoring of results will help to achieve success in promoting the restaurant through social media.

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A Proposal for AI-Driven Method for Strategic Business Decision-Making

Eva Ticina

Abstract This article proposes using AI to improve the business decision-making process, implemented within the Dara framework using the CausalNex model and integrating the interpretation of model results via ChatGPT-4. The study involved developing an experimental application for two specific business scenarios and comparing its effectiveness with standard ChatGPT-4. Results show that the app excels in detecting complex cause-and-effect relationships, surpassing the capabilities of ChatGPT-4. The utility of the approach in accurately visualizing patterns and responding to critical queries based on the interpretation of newly obtained data is demonstrated. The results suggest that the application can significantly contribute to strategic business decision-making, offering precise recommendations. Thus, the approach has potential to become an integral tool in shaping future strategic decision-making.

Keywords AI · Decision-making · Bayesian networks · Large language models · Business strategy · Causal relationships

1 Introduction

In today's highly competitive and rapidly changing business environment, it has become crucial for organizations to constantly seek innovative business strategies to gain a competitive advantage [1]. Artificial intelligence (AI) has become a focal point in recent times as businesses from different sectors aim to leverage its capabilities to enhance their strategic planning and decision-making [2].

Large Language Model (LLM) is a type of artificial intelligence system designed to understand and generate human-like text by training on a vast amount of digital text data [3]. As LLMs like ChatGPT and Llama3 become more popular, it's essential to

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grasp their strengths and weaknesses when it comes to making sense of the complex relationships that language involves [4].

Causal relationships in the business environment are often ambiguous and can change depending on numerous variables. LLMs like ChatGPT-4 may struggle with interpreting complex data where hidden variables, non-obvious connections, and contextual nuances are present [5]. Its susceptibility to errors can lead to significant inaccuracies and mistakes, which can negatively affect strategic business decision-making [6].

This research proposes a new approach for integrating Bayesian networks with Large Language Models (LLMs) to improve their causal reasoning and explainability. Bayesian networks are graphical models that represent causal relationships among variables in a dataset using probabilistic methods [7].

The primary research question of our study is whether integrating Bayesian networks with LLMs can effectively identify unclear causal relationships in a business environment. The secondary research question examines whether this integration method could be more effective for strategic business decision-making compared to standard LLMs like ChatGPT-4.

In order to get the answers on the research questions we develop an experimental application for two specific business scenarios based on the proposed method and compare its effectiveness with standard ChatGPT-4.

The article is divided into five parts. The introduction outlines the issue of LLMs struggling with causal relationships in the business environment. The literature review explores the role of artificial intelligence in management decision-making, discussing the application of LLMs in business along with its limitations. It examines the CausalNex model's ability to detect complex cause-and-effect relationships, describes Dara as an application framework designed to build apps that aid in evaluating business decisions and explains the use of WebUI. Methodology describes the methods used and describes the conducted experiment. The fourth section of the paper compares the outputs from the experimental application and ChatGPT-4, proposing an AI-driven method for strategic business decision-making. The fifth and final section summarizes the results, offers recommendations, and presents the conclusions.

2 Literature Review

2.1 Artificial Intelligence (AI) in Management Decision-Making

Artificial intelligence is a field in computer science that aims to replicate human brain functions such as sensing, understanding, responding, and problem-solving, using software in machines [8].

Artificial intelligence encompasses various definitions organized along two dimensions: thought processes and reasoning versus behavior, and fidelity to human performance versus ideal performance measure of rationality, aiming to create systems that do the right thing based on their knowledge [9]. Nowadays artificial intelligence is capable of processing and analyzing vast data sets more swiftly than the human mind, yet it faces challenges with simple tasks [10].

"Technology is tightly connected with business process" [11]. Artificial Intelligence (AI) is transforming business operations by enhancing efficiency, optimizing decision-making, and personalizing customer interactions [12]. In line with Saha [2], Artificial intelligence (AI) has become a pivotal force in strategic business decision-making, reshaping how organizations develop strategies and operational models. AI enables new business models, enhances operational efficiency, and aligns initiatives with strategic goals to secure competitive advantages. By processing vast volumes of data rapidly, AI augments human decision-making, allowing for the identification of patterns and insights that inform more accurate, data-driven decisions. This capability supports real-time decision-making and predictive analytics, enabling organizations to swiftly respond to market changes and optimize resources. Furthermore, the integration of AI within IoT systems allows devices to make autonomous decisions and interact with other devices or humans, further enhancing operational capabilities and strategic outcomes [13]. Moreover, AI-driven automation streamlines operations by handling routine tasks, thus boosting productivity and allowing human capital to focus on higher-value activities [2].

2.2 The Use of Large Language Models (LLMs) in Business

LLM, or Large Language Model, is a type of artificial intelligence that processes and generates human-like text based on the training it receives from vast amounts of written material [14]. LLMs include GPT, Gemini, Gemma, Llama3, Vicuna, and others. Among them, ChatGPT is the most popular LLM.

Arman and Lamiya [15] believe that ChatGPT is revolutionizing various industries including customer service, e-commerce, healthcare, finance, and marketing with its advanced natural language processing skills. In customer service, ChatGPT [16] offers round-the-clock support and handles unlimited queries simultaneously, reducing wait times and costs while boosting satisfaction. In e-commerce, it personalizes shopping experiences with tailored recommendations and simplifies tasks like order tracking. In finance, ChatGPT assists [17] with banking, fraud detection, and personalized investment advice, improving service and security. In marketing, it aids in lead generation, customer segmentation, and strategy refinement through feedback analysis.

The Nazir and Wang [5] study includes information that ChatGPT often struggles with causal reasoning, as its responses are based on patterns learned from training data, which may lack true causative understanding. This limitation can lead to outputs that appear logical but are factually incorrect, potentially spreading misinformation.

Additionally, its performance is highly dependent on the phrasing of user prompts, making it sensitive to subtle variations in input and sometimes resulting in misleading or inconsistent outcomes.

2.3 CasualNex for Detecting Complex Cause-And-Effect Relationships

According to CausalNex documentation [18], CausalNex is a Python library developed by QuantumBlack designed for data scientists and analysts to help them understand and predict the effects of different actions in a business setting. It uses a method called Bayesian Networks, which allows it to model complex relationships between various factors and determine how changes in one area can influence outcomes in another. This is particularly useful for strategic decision-making, as it goes beyond mere correlation and aims to understand cause and effect, enabling managers to make more informed decisions about interventions that could impact their business. Essentially, CausalNex provides a structured way to analyze potential business strategies and their effects before implementing them, reducing risk and increasing the likelihood of success.

2.4 Dara Application Framework

In line with the Dara documentation [19], the Dara application framework is a software development platform designed to streamline the creation of decision-making applications that utilize complex data analytics and machine learning algorithms.

2.5 Open WebUI

Open WebUI is a versatile, feature-packed, and user-friendly self-hosted web interface designed to function completely offline. It accommodates different LLM runners.

Table 1 A set of logical keywords

Artificial intelligence in decision-making		
Large language models in business		
Large language models	AND	Business
Artificial intelligence	AND	Decision-making
Artificial intelligence	AND	Business

3 Methodology

3.1 Literature Review

The first part of the study is dedicated to the *literature review and content analysis.* Our task was to provide the theoretical framework based on an analysis of existing knowledge. That is why we have chosen literature review. Therefore, we selected relevant literature, systematically processed it, analysed its content and presented findings. A search of published literature was conducted to gather related researches on the themes *Artificial intelligence in decision-making* and *LLMs in business*. Three databases, Scopus, Google Scholar, and IU Library, were searched from the year 2023 to 2024 using a set of logical keywords and syntax specific to each database (Table 1).

Works that were not related to the topic were excluded. To ensure including only substantial scientific work in this review, we only considered journal articles and published books. Using the exclusion criteria, we have chosen 37 entites as relevant for my case study and used 18. We also consulted the documentation for the tools used.

3.2 Experiment

In the next part, we performed an empirical research. In order to get the answers on the research questions we conducted an experiment. We developed an experimental application for two specific business scenarios based on the proposed method and compared its effectiveness with standard ChatGPT-4.

4 Results and Discussion

4.1 Developed Experimental Application

The semiconductor manufacturing dataset "SECOM Data from a semi-conductor manufacturing process" was downloaded by the following link [20]: https://archive.ics.uci.edu/dataset/179/secom/. The data consists of a multidimensional dataset containing 1567 instances with 591 attributes each. These attributes represent various measured signals and variables collected during the manufacturing process. The main task we faced was classification and detection of hidden causal relationships to determine which signals (features) are most important for predicting the success of the manufacturing process.

A dependency graph was constructed. Each node was assigned a probability and displayed graphically. Nodes with a probability below 0.5% were removed (Fig. 1).

Connections between the nodes were calculated. Probabilities were assessed, and all connections with a probability less than 0.8 and those nodes that remained unconnected to other nodes were removed. The final graph, which has significant connections, was obtained (Fig. 2).

The dataset was processed using CausalNex, and based on the highlighted graph, a Bayesian predictive model was built. The method fit_cpds from the CausalNex

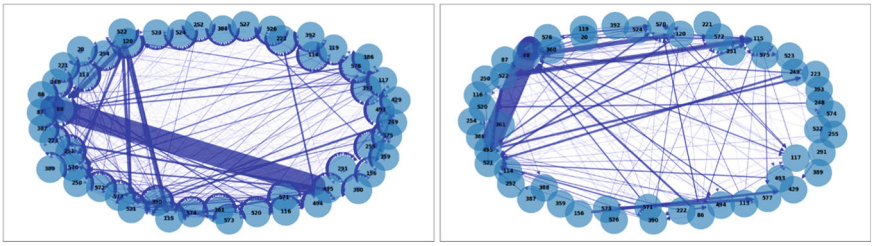

Fig. 1 Graph of general causal relationships of data and graph cleaned of insignificant connections with a probability < 0.5

Fig. 2 Graph of the node and edge structure on the left. On the right, the highlighted maximal subgraph on which the model training is based

{'527_0': {'precision': 0.9375, 'recall': 0.9868421052631579, 'f1-score': 0.9615384615384616, 'support': 76.0}, '527_1': {'precision': 0.987012987012987, 'recall': 0.9382716049382716, 'f1-score': 0.9620253164556962, 'support': 81.0}, 'accuracy': 0.9617834394904459, 'macro avg': {'precision': 0.9622564935064934, 'recall': 0.9625568551007146, 'f1-score': 0.9617818889970788, 'support': 157.0}, 'weighted avg': {'precision': 0.963044916866573, 'recall': 0.9617834394904459, 'f1-score': 0.9617896414639138, 'support': 157.0}}

Fig. 3 Screen of the appModel characteristics based on the results of classification obtained

library was used to train the Conditional Probability Distributions (CPDs) of the Bayesian network. This allowed the model to learn from data and make probabilistic inferences about the relationships between variables.

The model was trained and the accuracy of the model was evaluated (Fig. 3).

Precision: For the class 527_0 (successful test passage), the precision is 93.75%, which indicates a high probability that if the model predicts success, the product will indeed be successful. For the class 527_1 (test failure), the precision is even higher at 98.70%, which suggests that the model very reliably identifies potential failures.

Recall: For the class 527_0, recall is 98.68%, meaning that the model successfully identifies almost all real cases of success. For the class 527_1, recall is slightly lower at 93.83%, which is an excellent result.

F1 score: A balanced measure that takes into account both precision and recall, is 96.15% for 527_0 and 96.20% for 527_1, indicating high overall model efficiency in both categories.

Support: The number of cases in each class shows that the data is relatively evenly distributed between the two classes (76 vs. 81).

The overall accuracy of the model is 96.18%, making it a very reliable tool for predicting test outcomes based on collected data. This is particularly important in the context of semiconductor manufacturing, where the cost of errors can be high.

The trained model was connected through FAST API, the uvicorn server from the Dara framework, which is capable of interacting with the causal network. A WebUI was used to create the application interface in the browser, and APIs, including LLMs such as ChatGPT-4 and Llama3, were connected.

A web application was developed, capable of accessing any LLMs and augmenting them with a causal network. Its structure features a causal network on the back-end with a connected Dara server, while the front-end is implemented as a WebUI user-friendly interface in the browser (Fig. 4).

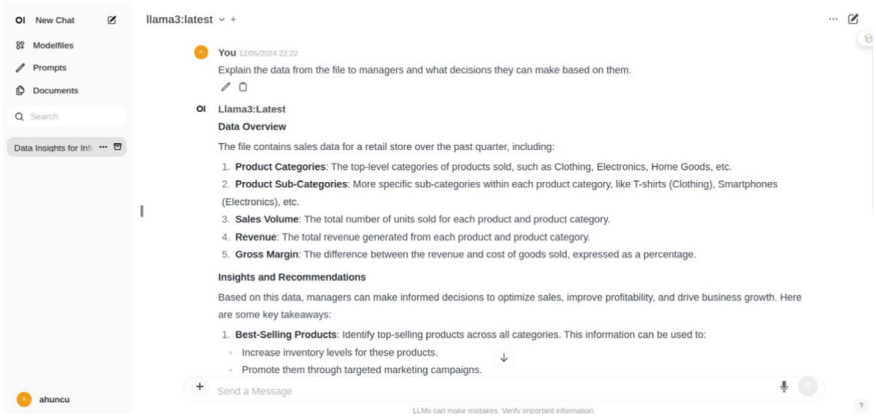

Fig. 4 Screen of the app

4.2 Comparison of the Outputs from the Experimental Application and ChatGPT–4

As part of the experiment, we augmented the causal network and accessed two LLMs: ChatGPT-4 and Llama3, asked the question and compared their responses with standard ChatGPT-4.

Question: Explain the data from the file for managers, what decisions can they make based on it.

ChatGPT-4 output:

The dataset you've provided is a manufacturing process data, specifically from a semiconductor manufacturing site. It contains 1567 entries and 592 features. The features include various measurements from the manufacturing process (like sensor data), and the final column Pass/Fail indicates whether the product passed quality assurance (− 1 for pass, 1 for fail).

Understanding the Data:

Time: Timestamp of when the measurement was taken.

0 to 588: These columns represent various sensor and measurement data. Their exact meanings are likely specific to the equipment and processes used in the semiconductor manufacturing.

589: Appears to be a final measurement or calculation derived from the preceding processes.

Pass/Fail: Outcome of the quality test for the semiconductor (binary classification, where − 1 indicates a pass and 1 indicates a fail).

Managerial Decisions:

Based on this data, a manager can make several key decisions:

Process Optimization: Identify which variables (sensors/measurement data) most influence product failures. Using statistical analysis or machine learning, they

can determine which stages of the manufacturing process are critical and require adjustment to improve product quality.

Predictive Maintenance: Analyze trends over time to predict when equipment is likely to fail or deviate from normal operating conditions. This can help in scheduling maintenance before actual failures occur, minimizing downtime.

Quality Assurance: Refine the quality control processes by identifying the threshold values for sensor readings that maximize the likelihood of passing the final quality assurance check. This might involve adjusting the Pass/Fail criteria based on historical data analysis.

Resource Allocation: Allocate resources more effectively by identifying bottlenecks or inefficiencies in the production line. Data on process times and pass rates can help prioritize investments in equipment upgrades or training for personnel.

Cost Reduction: By improving the accuracy of the Pass/Fail predictions using machine learning models, the company can reduce the cost associated with reworks and scrap material, optimizing overall production costs.

To move forward, it would be beneficial to perform deeper statistical analysis and possibly develop predictive models based on the extensive sensor and process data available in this dataset. This would enable more data-driven decision-making to improve the efficiency and output quality of the manufacturing process.

ChatGPT-4 employs a comprehensive, data-driven strategy that utilizes statistical and machine learning techniques to enhance decision-making and operational efficiency.

Llama3 output:

Data Overview

The file contains sales data for a retail store over the past quarter, including:

Product Categories: The top-level categories of products sold, such as Clothing, Electronics, Home Goods, etc.

Product Sub-Categories: More specific sub-categories within each product category, like T-shirts (Clothing), Smartphones (Electronics), etc.

Sales Volume: The total number of units sold for each product and product category.

Revenue: The total revenue generated from each product and product category.

Gross Margin: The difference between the revenue and cost of goods sold, expressed as a percentage.

Insights and Recommendations.

Based on this data, managers can make informed decisions to optimize sales, improve profitability, and drive business growth. Here are some key takeaways:

Best-Selling Products: Identify top-selling products across all categories. This information can be used to:

Increase inventory levels for these products.

Promote them through targeted marketing campaigns.

Consider expanding product lines or introducing new variations.

Slow-Moving Products: Identify products with low sales volume and revenue. This information can be used to:

Reduce inventory levels or discontinue slow-moving products.

Offer clearance sales or promotions to clear out inventory.

Consider discontinuing or replacing these products if they're not profitable.

Product Category Performance: Analyze the performance of each product category, including revenue and gross margin. This information can be used to:

Identify underperforming categories and adjust marketing strategies accordingly.

Focus on high-performing categories and expand product offerings within those areas.

Seasonal Trends: Identify seasonal patterns in sales data to anticipate fluctuations and plan inventory management accordingly.

Product Mix Optimization: Analyze the mix of products sold across different categories. This information can be used to:

Balance product offerings to optimize revenue and profitability.

Introduce new products or discontinue underperforming ones to improve overall product mix.

Decision-Making Opportunities.

Based on these insights, managers can make decisions such as:

Inventory Management: Adjust inventory levels for top-selling and slow-moving products.

Marketing Strategies: Develop targeted marketing campaigns for best-selling products and categories.

Product Development: Introduce new products or variations within high-performing categories.

Product Discontinuation: Discontinue underperforming products or categories to improve overall profitability.

Llama3 acts directly and straightforwardly, focusing on practical insights derived from the data without deep causal relationships.

Llama3 c CausalNex output:

To explain the data to managers, I'll break it down in simple terms:

What is this data?

This dataset contains information about a semiconductor manufacturing process at your site. It's like a report card for each product produced, with 1567 entries (or products) and 592 features (or measurements) that describe what happened during the manufacturing process.

What are these features?

The features include various sensor readings, which measure things like temperature, pressure, and other conditions during the manufacturing process. These sensors help you understand how well each product was made.

What's the Pass/Fail column mean?

The final column, Pass/Fail, shows whether each product passed or failed quality assurance tests (− 1 for pass, 1 for fail). This is important because it tells you if the product meets your quality standards or not.

What can we learn from this data?

By analyzing these features and the Pass/Fail results, we can identify patterns and trends that might help us improve our manufacturing process. For example:

Which sensors are most strongly correlated with passing or failing products?

Are there certain conditions during the process that are more likely to result in a pass or fail?

Can we use this data to predict which products are at risk of failing quality assurance tests?

What decisions can we make based on this data?

With this information, you can make informed decisions about your manufacturing process. Some examples:

Process optimization: Identify areas where the process can be improved to reduce failures or improve overall quality.

Quality control enhancements: Use sensor data to develop more effective quality control measures, such as adjusting temperature settings or monitoring pressure levels.

Predictive maintenance: Analyze patterns in the data to predict when equipment might fail or need maintenance, reducing downtime and improving overall efficiency.

Product design improvements: Identify areas where product design can be improved to reduce failures or improve performance.

By analyzing this dataset, you can gain valuable insights into your manufacturing process and make informed decisions to improve quality, reduce costs, and increase efficiency.

Llama3 + CausalNex involves a more sophisticated statistical analysis, offering a granular view of the manufacturing process through the lens of a Bayesian network.

GPT4 + CausalNex output:

From the provided data, it can be concluded that the model predicts conditional probabilities for various nodes (for example, nodes "527" and "390"). For node "527", the probabilities of transitioning to state 1 vary from 0.007386 to 0.988253 depending on conditions, and for node "390", the probabilities range from 0.333333 to 0.666667 for transitioning to state 1.

The transition probabilities in the context of Conditional Probability Distributions (CPD) in Bayesian networks indicate the likelihood that a node will take a certain state under given conditions or states of other nodes. These probabilities help to understand how changes in one or more factors can affect the outcome of the node of interest.

For a manager, this data can be useful to understand how various factors or conditions affect the likelihood of certain outcomes. For instance, understanding which conditions increase the probability of transitioning to state 1 for node "527" can help in making decisions about what strategies or changes in processes might be effective for achieving desired results. This may include strategic planning, risk management, or process optimization.

GPT4 + CausalNex utilizes Bayesian statistical methods to provide a deeper, quantitative understanding of the data, facilitating precise predictions and targeted process improvements.

4.3 Comparison of the Outputs Obtained from the ChatGPT-4 and ChatGPT-4 with CausalNex

ChatGPT-4 with Bayesian Network dives deeper into probabilistic analysis, which is crucial for understanding specific dependencies and outcomes within the manufacturing process. ChatGPT-4 [19], while comprehensive, offers a broader overview with practical applications but less focus on the probabilistic interconnections.

ChatGPT-4 gears its recommendations towards overall process improvements and efficiency enhancements using data-driven methodologies. GPT-4 with Bayesian Network emphasizes the specific impacts of altering conditions within the process, using a more focused and detailed statistical approach.

ChatGPT-4 provides actionable insights that are broadly applicable, making it suitable for managers looking for general improvements. GPT-4 with Bayesian Network offers a toolset for managers who need to understand the detailed dynamics of their manufacturing processes, making it ideal for precise and critical decision-making scenarios.

4.4 Comparison of the Outputs Obtained from the Llama3 and Llama3 with CausalNex

Llama3 provides a user-friendly, accessible interpretation, suitable for quick decision-making without requiring statistical expertise. Llama3 with Bayesian Network goes deeper, offering detailed probabilistic analysis that can uncover more intricate patterns and dependencies not immediately apparent in the basic analysis.

Llama3's insights are immediate and practical, making it easy for managers to implement recommendations quickly. Llama3 with Bayesian Network's insights are detailed and predictive, suitable for strategic decisions based on deep statistical forecasting and risk assessment.

4.5 Comparison of the Outputs Obtained from the LLMs with CausalNex and Standard ChatGPT-4

The integration of Bayesian networks allows this model to predict outcomes more accurately by considering the conditional probabilities of various nodes or parameters. This is particularly useful for predictive maintenance and quality assurance, where anticipating failures or quality issues before they occur can save significant costs and enhance operational efficiency.

While ChatGPT-4 offers broad, data-driven insights and Llama3 with Bayesian Network provides deep, statistical analysis, ChatGPT-4 with Bayesian Network marries these approaches, offering a more holistic and nuanced view of data. It is particularly suitable for complex decision-making environments where both a comprehensive understanding of large datasets and detailed probabilistic analysis are required to make informed decisions. This makes it an optimal choice for users who need a robust analytical tool that can navigate both macroscopic trends and microscopic data interactions efficiently.

4.6 A Proposal for AI-Driven Method for Strategic Business Decision-Making

1. Download and clean the dataset.
2. Process the dataset with CausalNex and create a model.
3. Connect the model through the fast API server uvicorn from the Dara framework.
4. Connect WebUI.
5. Connect the API of the ChatGPT-4 model or any other LLM.
6. Ask questions in the chat of the developed web application and enjoy.

5 Discussion

To answer the research questions, an experiment was conducted. A model was developed based on a specific dataset and enhanced with Bayesian networks. Subsequently, a web application was created using the Dara Framework API server and WebUI interface for two specific business scenarios: ChatGPT-4+ CausalNex and Llama3+ CausalNex.

Based on the obtained results, integrating Bayesian networks with LLMs can effectively identify unclear causal relationships in a business environment. This integration method could be more effective for strategic business decision-making compared to standard LLMs like ChatGPT-4.

We agree with Nazir that LLMs like ChatGPT-4 may struggle with interpreting complex data involving hidden variables, non-obvious connections, and contextual nuances [5].

The results of comparing outputs from LLMs with Bayesian networks and standard ChatGPT-4 indicate that while ChatGPT-4 offers broad, data-driven insights and Llama3 with a Bayesian Network provides deep, statistical analysis, ChatGPT-4 with a Bayesian Network combines these approaches, offering a more holistic and nuanced view of data. This is particularly suitable for complex decision-making environments where both a comprehensive understanding of large datasets and detailed probabilistic analysis are required to make informed decisions. This makes it an optimal choice for users who need a robust analytical tool that can efficiently navigate both macroscopic trends and microscopic data interactions.

Models augmented with precise knowledge of hidden causal relationships, extracted from data on-the-fly, demonstrate more substantive responses that are more adequate and useful. Although we built a simple experimental Bayesian network model, it even helped a less powerful Llama3 with 8-bit quantization handle a complex dataset. The conclusion regarding local models is that by supplementing them with specialized models, they can indeed cope with complex data on domestic computer equipment. As for ChatGPT-4, a causal model also significantly enhances its accuracy. We consider the direction of augmenting large LLMs not only with general multimodal models but also with small specialized models to be very promising.

By answering on the research questions, this article contributes to the research field of AIs for business decision-making. The practical outcome of this project is a proposed method that businesses can integrate.

For businesses aiming to stay competitive and adaptive in a complex market, integrating Bayesian Networks (BNs) with Large Language Models (LLMs) offers a transformative approach to data analysis and decision-making. This integration enables companies to process and understand vast amounts of text-based data while accurately predicting outcomes and understanding complex dependencies. Businesses can utilize this powerful combination for more precise forecasting in sales, demand, and market trends, thus enabling proactive strategic adjustments. Additionally, the risk assessment capabilities of LLMs equipped with BNs are essential for informed decision-making in areas like financial planning and resource allocation, as they can predict various outcomes and assess potential risks effectively. The ability to map relationships among process variables can also help identify operational bottlenecks and optimize processes for improved efficiency and cost reduction, particularly beneficial in sectors like manufacturing and logistics. By harnessing the dual capabilities of qualitative analysis and quantitative predictions, businesses can align strategic planning with data-driven insights, tailoring products and services to enhance customer satisfaction and loyalty, thereby driving growth and sustainability.

Thanks to the ability to use local LLMs and Causalnex models, data can be stored on-site, eliminating the risk of information leaks. There is no need for an internet connection, which adds a level of security and reliability. Additionally, using local

models can be economically advantageous, as they often do not require additional costs.

The work was limited to 15 pages, which is why we only verified whether the proposed methods work based on a single model. Future research should develop more models and investigate their behaviors when enhanced with different LLMs.

6 Conclusion

The article is structured into five parts. The introduction highlights the challenge of LLMs grappling with causal relationships within the business environment. The literature review delves into the role of artificial intelligence in management decision-making, discussing the use and limitations of LLMs in business contexts. It evaluates the CausalNex model's proficiency in identifying complex cause-and-effect relationships, introduces Dara as a framework for developing applications that support business decision evaluation, and outlines the functionality of WebUI. Methodology describes the methods used and describes the conducted experiment. The fourth section compares the outputs from the experimental application with those of ChatGPT-4, advocating an AI-driven approach to strategic business decision-making. The concluding section summarizes the findings, offers recommendations, and presents the final conclusions.

The study demonstrates that integrating Bayesian networks with LLMs can effectively clarify ambiguous causal relationships in business settings. This integration could prove more advantageous for strategic decision-making than using standard LLMs like ChatGPT-4 alone.

By addressing the research questions, the article contributes significantly to the field of AI in business decision-making. The practical outcome of this research is a method that businesses can adopt to enhance decision-making processes.

The method involves downloading and cleaning the dataset, processing it with CausalNex to create a model, connecting the model through the fast API server uvicorn from the Dara framework, connecting WebUI, and linking the API of the ChatGPT-4 model or another LLM. Users can then pose questions in the chat of the developed web application and engage with it interactively.

The scope of the study was confined to 15 pages, limiting the verification to whether the proposed methods function effectively with a single model. Future research should expand on developing more models and exploring their performance when augmented with various LLMs.

It is recommended that businesses integrate Bayesian networks with LLMs to remain competitive and adaptive in a complex market, thereby enhancing strategic decision-making. Leveraging both qualitative analysis and quantitative predictions allows businesses to align strategic planning with data-driven insights, tailor products and services to improve customer satisfaction and loyalty, and ultimately drive growth and sustainability.

In conclusion, the article offers valuable theoretical insights and practical applications, enhancing knowledge in the field and providing an effective methodology to facilitate strategic business decision-making.

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Building Food Security Resilience in Ukraine: The Autoregressive Approach to Food Price Forecasting

Larysa Zomchak and Tetiana Kukhotska

Abstract This research describes the application of a Vector Autoregression (VAR) model to forecast food prices in Ukraine. The analysis covers the period from January 2014 to December 2021 and focuses on wheat, corn, sunflower, pork, gasoline prices, and European wheat prices. The analysis identified a positive trend in prices for wheat, corn, sunflower, and pork over the studied period. A VAR model was built using price data with three lags to capture interrelationships between the variables. The model achieved high determination coefficients (0.93–0.98) indicating a good fit between the model and the data. The model forecasts a downward trend for wheat prices with limited volatility. The model excludes external factors such as the 2022 war and its geopolitical consequences, potentially leading to inaccurate predictions. The VAR model provides valuable insights into historical food price trends in Ukraine. However, its limitations in handling non-linearities and unforeseen events make it less suitable for forecasting during periods of high market uncertainty, such as wartime. Such a food price forecasting system could provide more accurate short-term forecasts, allowing policymakers to take proactive measures. For instance, if a price spike is predicted for a specific commodity, targeted subsidies or import agreements could be implemented to mitigate food insecurity. By incorporating dynamic food price forecasting into resilience-building strategies, Ukraine can be better prepared to navigate market uncertainties and safeguard its food security.

Keywords Forecasting · Price · Food · Wheat price · Time series · Agriculture · Ukraine · Food security · Resilience

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1 Introduction

The war in Ukraine has thrown the nation's food security into sharp relief. Building resilience requires a multi-pronged approach. Firstly, utilizing machine learning techniques to forecast food prices can help anticipate shortages and stabilize markets. Secondly, strengthening the financial security of the agricultural sector, allows farmers to maintain production and adapt to disruptions. Finally, long-term strategies are needed to enhance the overall resilience of the food system. This could involve diversifying crops, improving storage infrastructure, and fostering regional food security networks. By integrating food price forecasting, financial support for agriculture, and long-term resilience building, Ukraine can navigate the current crisis and emerge with a more secure food system.

Food security and food price forecasting are intertwined issues, particularly relevant in regions facing complex challenges like Ukraine. Existing research explores this connection from various angles. Studies like [1] analyze economic indicators to identify food security vulnerabilities in specific regions, pinpointing areas of concern. Research [2] examines factors impacting the competitiveness of Ukrainian food products. Strengthening competitiveness can contribute to long-term food security. Authors of [3] emphasize the importance of increasing data availability in Ukrainian agriculture for improved food security planning. Better data allows for more accurate forecasting. The article [4] discuss the rise of digital technologies in agriculture, including machine learning. These techniques hold promise for food price forecasting. Existing research, like [5] demonstrates traditional forecasting models for specific commodities. However, these models struggle during periods of disruption. The research [6] highlight the need to account for risks and uncertainties in agricultural production models, a concept equally applicable to food price forecasting.

Current research suggests a need for more robust food price forecasting models capable of handling disruptions. Machine learning offers a promising avenue for exploration.

The study [7] focuses on cassava processing, a staple food in many regions. The research [8] on supply chain management for Thai food exports highlights the importance of efficient food distribution systems. The research [9] on business status updates in the food and beverage industry. The study [10] on food safety management using case-based reasoning can indirectly contribute to food security by minimizing food spoilage and ensuring the availability of safe food for consumption.

Methods used in medical applications [11, 12], cryptography [13], robotics [14] and can be useful in economics.

While the use of fuzzy logic for food commodities isn't directly related to food security, it could potentially be applied to model food price fluctuations, which can impact food affordability, another key aspect of food security [15].

Several studies have explored quantitative methods in economic contexts. Reference [16] applied conjoint analysis to assess industrial park competitiveness, demonstrating the use of quantitative techniques in economic forecasting. And [17] applies

cohort analysis. Authors of [18] investigated incorporating random factors into complex microeconomic system models. Their work is particularly relevant as it aligns with the need to account for uncertainties in food price forecasting due to the war's impact. And [19] propose a data-based approach in business.

Existing research highlights the importance of information management systems [20] and predictive modeling [21] in project planning, which can inform data organization and future trend considerations within food price forecasting.

References [22, 23] highlight the existing threats to food security in Ukraine even before the war. Their work emphasizes the need for resilient food systems that can withstand disruptions.

The war in Ukraine has significantly exacerbated food security concerns globally, as evidenced by [24, 25]. Reference [26] emphasize the importance of financial security for the Ukrainian agricultural sector. This financial stability is crucial for maintaining food production and affordability. References [27, 28] showcase the potential of machine learning for predicting economic dynamics and food security transitions. This offers promising avenues for forecasting food availability and price fluctuations. Reference [29] explore the use of combined forecasting models to predict agricultural prices, considering spatial and temporal factors. Applying such models to the Ukrainian context could be valuable. Reference [30] establish the clear link between food prices and food security. Food price fluctuations can significantly impact affordability and access to food, especially for vulnerable populations. While the reviewed research offers valuable insights, there's a need for further exploration: developing and implementing quantitative models specifically tailored to forecast food security and prices in Ukraine under volatile conditions and investigating the long-term impacts of the war on Ukrainian food security and devising resilience-building strategies.

2 Materials and Methods

2.1 Commodity Market in Ukraine (with Ascent on Grain Market)

One of the main markets for food products was chosen for the study—the grain market. The grain sector of Ukraine is a strategic branch of the country's economy, which determines the supply and cost of the main types of food for the population, in particular grain processing and animal husbandry products. The grain industry is a source of sustainable development of most branches of agriculture and the basis of the country's agrarian exports [31]. The grain market is based on the production of various types of grain crops, which are then sent for processing. In general, the volume of production of grain and leguminous crops during 2000–2021 was characterized by positive dynamics of increase in quantity, but also characterized by some instability. This trend can be explained by the sensitivity of grain crops to the state of natural and

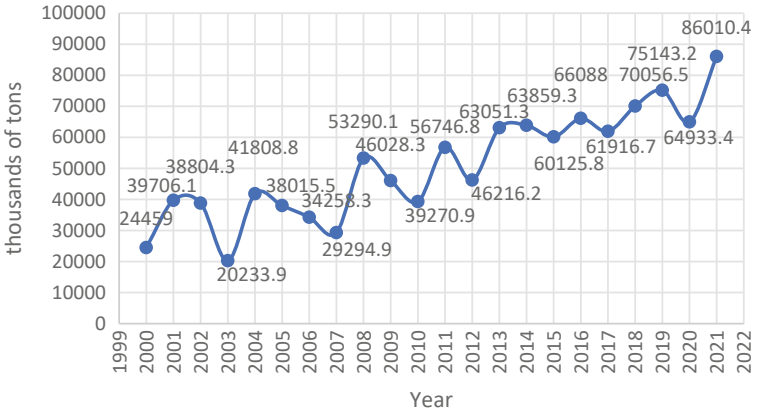

Fig. 1 Dynamics of the production volume of grain and leguminous crops during 2000–2021, thousand tons. *Source* Constructed by the authors on data [32]

climatic conditions. You can trace the dynamics of changes in production volume in Fig. 1.

If we look at the main indicators of grain and leguminous crops by crop and compare them in 2000 and 2021, we can see that there is an increase in the production of wheat, barley, corn and legumes and a decrease in rye, oats, millet, buckwheat and rice Also, during this period, the sown area for all crops except wheat and corn decreased. Examining export and import operations on the grain market during 2019–2021, we can observe a decrease in wheat exports, which in 2021 compared to 2019 decreased by 1124.43 thousand tons. Also, the export volumes of corn and buckwheat decreased by 12,568.18 and 0.65 thousand tons, respectively. On the other hand, exports of such crops as rye, barley, oats, millet, and rice experienced an increase in volumes. At the same time, it can be noted that the main competitors of wheat on the market are Australia, the USA, and France. Analyzing the main buyers of domestic grain, it can be seen that during the considered period the leading importers are Egypt, Turkey, Poland, India, Germany, and Pakistan. As for the import of grain during 2019–2021, it decreases for such crops as rye, oats, corn, and rice and increases for such crops as wheat, barley, plain, buckwheat [32].

The main sellers of products for the country are Hungary, Belarus, Kazakhstan and Russia. Since the end of 2021, the prices of commodities such as grains and vegetable oils have set new records, surpassing even the levels seen during the global food price crisis more than a decade ago.

The war in Ukraine added tension to the already difficult market for agricultural products. Now, due to the invasion of Russian troops into Ukraine, prices have soared even higher. This primarily affected the import-dependent countries of the Middle East and North Africa (MENA), as well as sub-Saharan Africa, which are largely dependent on Russian and Ukrainian wheat [33]. Despite their limited position in the global economy, with only approximately 2% of global GDP, Russia and Ukraine are

considered the "breadbasket of the world" and are important producers and exporters of vital agricultural commodities, minerals, fertilizers and energy. Russia and Ukraine together account for about 30% of world exports of wheat, 20% of corn, mineral fertilizers and natural gas, and 11% of oil [23].

The loss of Ukrainian agricultural production due to the war is of global significance, as Ukraine is a major exporter of grains and oilseeds—especially corn and wheat, as well as barley, sunflowers and sunflower oil, among other commodities. The expansion of Ukrainian exports occupied an increasing share of world trade. During the three pre-war marketing years (2018/19, 2019/20 and 2020/21), Ukrainian exports accounted for 15% of world corn trade and 10% of world wheat trade. During this period, Ukraine was the fourth largest exporter of corn and the fifth largest exporter of wheat in the world.

Ukraine is widely known as a low-cost grain producer. A comparison of international production costs shows that Ukrainian farms have significantly lower costs per acre and higher returns than producers in other major grain exporting countries. This allows Ukraine to compete in the most price-sensitive export markets, particularly in the Middle East and North Africa. The loss of Ukrainian grain production due to the war is costly, as this production can only be replaced by more expensive goods from other production regions [23]. The sustainability aspects of Ukrainian economy are discussed in [34]. A complete cessation of wheat exports from Russia and Ukraine would lead to severe shortages in many countries with developing markets. There will be an acute risk not only of economic crises in some countries, but also of humanitarian disasters with a sharp increase in poverty and hunger. A disruption in fertilizer production risks making these disruptions longer, stressing next year's agricultural supply. In many countries of the Middle East, wheat imports from Russia and Ukraine account for about 75% of the total volume of wheat imports [35].

Disruptions in exports from the Black Sea region and high prices further destabilize food security in the Middle East and North Africa (MENA). However, global demand for wheat is expected to be met by countries such as Australia, Brazil and the US, which will increase exports to fill the gap left by Russia and Ukraine [33]. The impact on the corn market mainly depends on Ukraine, as Russia is a small producer. Ukraine is the fourth largest exporter of corn in the world, accounting for about 15% of the world market. After a drought that affected production in Brazil and Argentina, the market is tight, and the war threatens the next harvest and Ukraine's ability to export. In addition, after problems with the supply of corn and wheat, the war increased the demand for rice fodder, leading to sharp volatility in rice prices. In the Asian rice market, the influx of domestic and international feed demand reduced the supply of broken rice. Although market balances as of June 2022 suggest adequate supply of wheat and other controlled commodities globally, markets remain tight. In addition, adjustments in trade flows and rising energy costs lead to higher international prices for agricultural commodities.

In March 2022, the FAO Food Price Index (FFPI) reached its highest level since 1990 at 159.7 points. The FFPI declined slightly in April and May 2022, although still 30% above its value in the corresponding months of the previous year. The increase in prices is particularly significant for vegetable oils and grains. While the

vegetable oil index has started to decline since March 2022, the grain price index continues its upward trend. Vulnerable segments of the population in low-income and food-scarce countries, which spend a significant proportion of their income on food, are particularly vulnerable to such price increases [36].

Food prices remain at a very high level. In April 2023, the FAO food price index, which tracks monthly changes in international food prices, reached an average value of 127.2 points, which is 0.6% higher than in March. Although this figure is 19.7% lower than in April 2022, it remains 5.2% higher than in April 2021. In many countries, high inflation of food prices is observed, which is especially relevant for low- and middle-income countries. It is also worth noting that 87.3% of high-income countries face high food price inflation. The countries of Africa, North America, Latin America, South Asia, Europe and Central Asia were the most affected.

During the war, in 2022–2023, production of simulated crops decreases. Although corn acreage is expected to predominate, Ukraine will still produce more wheat than all other crops because of yield differences. Corn, however, will become its main competitor. Although corn takes a big hit during the war, it recovers very quickly. The amount of wheat and barley produced is less affected by the war, and therefore the pace of recovery is less dramatic. Rye and oats also suffer significantly. Their rate of recovery is predicted to be quite smooth.

Exports of grain and oil crops will largely follow production. In particular, wheat and corn exports, as well as barley exports, will increase after the 2022–2023 shock, but will not reach pre-war levels until 2030, however. Exports of oats and rye will fully recover, mainly because their pre-war exports were relatively small. The export of oil crops will slowly recover and will not reach pre-war levels [37].

Exports of Ukrainian grain through Black Sea ports have fallen since the end of the Black Sea Grain Initiative (BSGI) in mid-July 2023, although not as much as many expected. Since the expiration of the BGSI, more than 1.3 million tons of agricultural products have been exported from the Black Sea ports of Ukraine through the newly created coastal corridor of humanitarian shipping. However, increasing export capacity through the Danube River ports continues to play a more decisive role. In general, from the beginning of the 2023/24 marketing year on July 1, 2023, Ukraine exported about 8.7 million tons of grain and leguminous crops (about 2 million tons of them in October). This is about 30% less than the 12.3 million tons exported during the same period last year.

Average global wheat prices in 2024 are forecast to be 2.9% lower than average prices in 2023, according to the World Bank's latest analysis in October. While average corn prices in 2024 are projected to be 8% lower than average prices in 2023. While the decline in agricultural exports from Ukraine continues to add tension and volatility to global markets, trends in Ukrainian export operations are becoming less relevant to overall expectations for global commodity markets as supply chains and the global market have largely adapted.

According to a NASA Harvest analysis based on satellite images, approximately 5.2–6.9 million acres of agricultural land in Ukraine (6.5–8.5% of the country's total area) have been neglected since the beginning of the war in Ukraine. Most of the abandoned lands are located near the front line or in the territories that were recently

returned to the control of Ukraine. Despite shrinking agricultural land and other challenges facing Ukrainian farmers, this year's harvests have increased due to favorable weather. In addition, the latest survey conducted by the Ministry of Agriculture and Food of Ukraine shows that most farmers do not plan to reduce the area sown for winter crops (in October/November). However, according to the Center for Strategic and International Studies (CSIS), Ukraine faces extreme landmine contamination on agricultural land, with various estimates indicating contamination of 1814–9652 square miles of agricultural land [38].

2.2 Vector Autoregressive Model in Economics

Univariate autoregression is a one-equation, one-variable linear model in which the current value of the variable is explained by its own lag values. A VAR is an n-equation, n-variable linear model in which each variable is in turn explained by its own lagged values and the current and past values of the remaining n − 1 variables. This simple framework provides a systematic way to capture dynamics in multiple time series, and the statistical toolkit that comes with VAR is easy to use and interpret. As argued by Sims and others in a number of influential early papers, VAR models promised to provide a consistent and robust approach to data description, forecasting, structural inference, and policy analysis.

The structure of the VAR model is such that each variable is a linear dependence of the past lags of this variable and the lags of other variables. VAR models are usually built on stationary time series. If the series are non-stationary or integrated of the 1st order—I(1) and cointegrated, then vector error correction models (VECM) are built.

The order of the model is determined by the order of the lag. At the same time, the condition that the series are stationary processes must be fulfilled.

There are the following forms of VAR models: the condensed form of the VAR model; recursive VAR models; structural VAR models; VAR models with error correction (VECM models); structural VAR models with error correction for integrated series (SVECM models).

The combined form of simultaneous equations contains only exogenous variables as explanatory variables. The condensed form is necessary to obtain forecast values of endogenous variables and to obtain estimated values of endogenous variables and unbiased estimates of parameters of the structural form of simultaneous equations. Analytical view of the summary form:

$$\begin{cases} Y_1 = \alpha_{10} + \alpha_{11}x_1 + \cdots + \alpha_{1m}x_m + \delta_1 \\ Y_2 = \alpha_{20} + \alpha_{21}x_1 + \cdots + \alpha_{2m}x_m + \delta_2 \\ \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots \\ Y_n = \alpha_{n0} + \alpha_{n1}x_1 + \cdots + \alpha_{nm}x_m + \delta_n \end{cases} \quad (1)$$

where

α_{i0}	intercept;
αij	coefficients of predetermined variables, which are a function of the coefficients of the structural form of the model $i = \overline{1, n}$, $j = \overline{1, m}$;
δi	is the random component (error) of the ith equation of the reduced form of the model ($i = \overline{1, n}$);
Y1, Y2, …, Yn	endogenous variables;
x1, x2, …, xm	exogenous variables.

In a recursive VAR model, the error for each variable is uncorrelated with the error for the previous variable. The right-hand side of the first vector autoregression equation does not contain the current observation of the other variables; the second equation contains the current level of only the first variable; the third is the current levels of the first and second equations, respectively, and so on. The recursive form of the VAR for k variables and the number of lags p is the autoregression model:

$$\begin{cases} x_{t1} = \alpha_1 + \alpha_{11}^1 x_{t-1,1} + \alpha_{12}^1 x_{t-1,2} + \cdots + \alpha_{1k}^1 x_{t-1,k} + \alpha_{11}^2 x_{t-2,1} + \alpha_{12}^2 x_{t-2,2} \\ \qquad + \cdots + \alpha_{1k}^2 x_{t-2,k} + \alpha_{11}^p x_{t-p,1} + \cdots + \alpha_{1k}^p x_{t-p,k} + \varepsilon_{t1}, \\ x_{t2} = \alpha_2 + \alpha_{21}^0 x_{t1} + \alpha_{21}^1 x_{t-1,1} + \cdots + \alpha_{2k}^1 x_{t-1,k} + \alpha_{11}^2 x_{t-1,1} + \alpha_{22}^2 x_{t-1,2} \\ \qquad + \cdots + \alpha_{2k}^2 x_{t-2,k} + \alpha_{21}^p x_{t-p,1} + \cdots + \alpha_{2k}^p x_{t-p,k} + \varepsilon_{t2}, \\ \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\ x_{tk} = \alpha_k + \alpha_{k1}^0 x_{t1} + \alpha_{k2}^0 x_{t,2} + \cdots + \alpha_{k,k-1}^0 x_{t,k-1} + \alpha_{k1}^1 x_{t-1,1} + \alpha_{k2}^1 x_{t-1,2} \\ \qquad + \cdots + \alpha_{kk}^1 x_{t-1,k} + \cdots + \alpha_{k1}^p x_{t-p,1} + \cdots + \alpha_{kk}^p x_{t-p,k} + \varepsilon_{tk} \end{cases} \tag{2}$$

xtk	a variable that depends on previous values at each time step t;
αtk	coefficients of predefined variables, which are a function of the coefficients of the structural form of the model;
ε_{ti}	random component (error) for each variable xt at each time step t;
p	the number of prior values considered for each variable xt;
α_{ij}^q	coefficient of a predetermined variable xi on q-step.

The structural form of the VAR model contains restrictions that are predetermined by economic processes. This model is usually used for structural reduction—checking the conformity of economic data with a specific economic theory and policy analysis. Aggregate and recursive forms of the VAR model are statistical models that do not contain any economic theoretical constraints, except for the choice of variables. As a rule, these forms are used for data description and forecasting.

The structural form of VAR models is a system in which variables x1 and x2 have a mutual influence. The VAR model in its simplest form is an order I model and contains two variables with a lag of 1, the number of model equations is equal to the number of variables. It looks like this:

$$\begin{cases} x_{t1} = \alpha_{10} - \alpha_1 x_{t2} + \beta_{11} x_{t-1,1} + \beta_{12} x_{t-1,2} + u_{t1} \\ x_{t2} = \alpha_{20} - \alpha_2 x_{t1} + \beta_{21} x_{t-1,1} + \beta_{22} x_{t-1,2} + u_{t2} \end{cases} \quad (3)$$

xtk a variable that depends on previous values at each time step t;
α_{i0} intercept;
αij coefficients of predetermined variables, which are a function of the coefficients of the structural form of the model $i = \overline{1, n}$, $j = \overline{1, m}$;
βij coefficients of predetermined variables, which are a function of the coefficients of the structural form of the model $i = \overline{1, n}$, $j = \overline{1, m}$;
u_{tk} random component (error) of the equation of the structural form of the model.

The main difference of VAR models is that the distribution of variables into endogenous and exogenous variables is not carried out a priori. All variables are assumed to be endogenous. It is obvious that shocks (or disturbances) u_{t1}, u_{t2} affect both x1 and x2. If $a1 \neq 0$, then u_{t2} has an indirect effect on the change in x1; accordingly, if $a2 \neq 0$, then u_{t1} has an indirect effect on the change in x2.

The choice of the type of model depends on: the purpose of the VAR model (for example, if the VAR model is used only for forecasting, then identification is not required at all); provisions of economic theory to establish the order or limitations of variables; results of stability testing and analysis of impulse response functions.

Building a VAR model includes the following stages:

Definition of variables
Stationarity check
Checking for causality
Evaluation of VAR model parameters
Interpretation of simulation results.

Vector autoregressive models can be used only for stationary time series. If the indicators being studied are not stationary processes, then they must be reduced to stationary differences by the operator. It should be noted that, as a rule, for financial time series, the application of first and second difference operators is sufficient to reduce the series to a stationary one. It is also possible to apply the difference operator to the values of logarithms of the time series, which also makes it possible to significantly reduce the order of integration.

If some of the indicators are stationary in levels, and some have a higher order of integration, you should make sure that the model does not contain pure stationary and trend-stationary variables at the same time, because this can negatively affect the quality of parameter estimates. In this case, the trend-stationary series should be transformed into a pure stationary process by the first difference operator.

At the next step of building the model, various causality tests are used, including the Johansen test, Engle–Granger test, etc., in order to identify the interdependence between indicators in the VAR model. Causality between indicators is investigated using the Granger test.

Next, the parameters of the selected model are evaluated. A VAR model in its structural form cannot be estimated by ordinary least squares because xt1 is correlated

with the random variable ut2 and xt2 is correlated with xt1. But, as in the case of systems of simultaneous equations, it is possible to estimate the VAR in the reduced form, and then, based on its coefficients, find the coefficients of the structural system. Due to the existence of problems when estimating the unknown parameters of VAR models in the structural form, VAR models in the reduced form are used in practice. It is quite easy to estimate the parameters of the reduced VAR form. Each of the equations contains the same regressors, and there are no mutual restrictions between the equations.

The best estimate of each equation can be obtained using the method of least squares. It can be shown that in this case (with the same number of lags in each equation of the system) estimation by the method of least squares gives consistent and asymptotically efficient estimates. Note that the assumption of the absence of serial autocorrelation is not decisive in this case, since it can be absorbed by increasing the number of lags in the system. If some equations of the VAR system in the reduced form contain variables that are not added to other equations, then estimation of the system based on the method of least squares is impossible. In this case, the VAR model must be estimated by the method of hypothetically unrelated SUR regressions, which provides effective estimates with different numbers of lags in the system equations. Since the matrices of the estimated coefficients of the VAR model are difficult to interpret directly, the estimation results are usually given by some functions of these matrices. Such statistics include impulse response functions and prediction error decomposition, Granger causality test statistics.

It should also be noted that the number of lags that must be included in The VAR model is a certain compromise between a possible specification error and a sharp reduction in the degrees of freedom. If r lags are included in the model, then each of the n equations of the system includes n * p coefficients plus an intersection. This usually requires a sufficiently long time series. Therefore, the optimal choice of the order of the VAR model is a serious problem in the analysis of time series.

And the last step is the interpretation of the simulation results, namely: the analysis of the impulse response function. The impulse response function shows a change in endogenous indicators in response to a shock (a change in one of the system's disturbances).

It should be noted that in VAR-models in the reduced form, the interpretation of the impulse function is complicated, since the disturbances in such a system, in contrast to the structural form, are correlated among themselves. If a correlation exists, then there is, accordingly, a common component that cannot be associated with only one variable. One of the compromise solutions to this problem consists in artificially assigning the effect of the common component to the first variable of the VAR model. Of course, this does not solve the problem as a whole, besides, changing the order of the equations changes the impulse function itself, which complicates its interpretation. Another way out is to represent disturbances of the reduced form of VAR models through disturbances of the structural form, which are assumed to be uncorrelated with each other.

3 Dynamics of Food Prices in Ukraine

According to the data that cover the period from January 2014 to December 2021, it is possible to single out a few critical trends and changes in food goods prices.

To conduct the research, the prices of such products as wheat, corn, sunflower and pork were taken.

There may be correlations between the prices of wheat, corn, sunflower and pork, as these agricultural products are often used in the food industry and may be interchangeable. Examples of dependence between these indicators can be competition for land resources, that is, farmers often have the opportunity to grow wheat or corn on the same land. If the price of corn rises, farmers may focus more on growing corn while reducing wheat production, and vice versa. Or another example would be oil crops, including sunflower, used to grow feed for animals such as broilers and pigs. A change in the price of sunflower can affect the cost of feed production, which can affect the prices of meat and other animal products. This, in turn, may affect consumer demand and the cultivation of other crops, including wheat. Also, world wheat prices can affect wheat prices in Ukraine due to a number of factors, such as exports, foreign economic situation, events on the world market, world demand and seasonality. Changes in world prices can cause fluctuations in wheat prices in Ukraine, which can affect producers, consumers and the country's economy as a whole. Understanding these impacts helps governments and businesses make decisions about wheat production, trade and consumption.

Graphically, the dynamics of price changes for corn, sunflower, and pork are shown in Figs. 2, 3 and 4.

For the researched period, observed growth in corn. Value prices from January 2014 (1126.1 UAH/t) to December 2021 (6245.5 UAH/t) shows a stable positive

Fig. 2 Dynamics of the cost of selling pork during 2014–2021. *Source* Built by the authors based on [39]

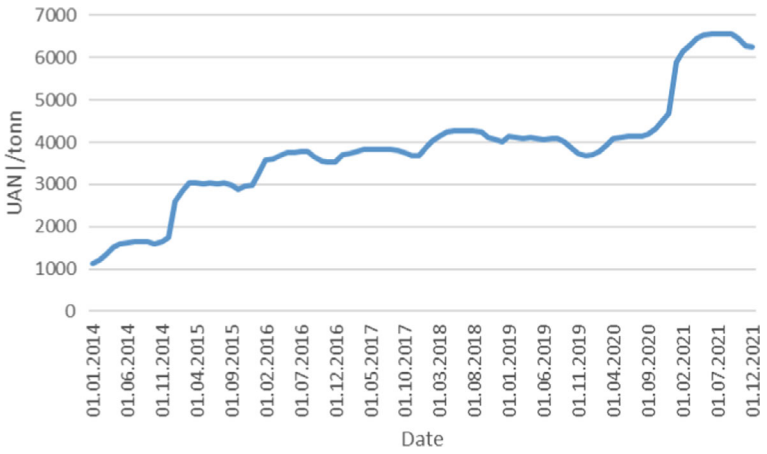

Fig. 3 Dynamics of the cost of corn during 2014–2021. *Source* Built by the authors based on [39]

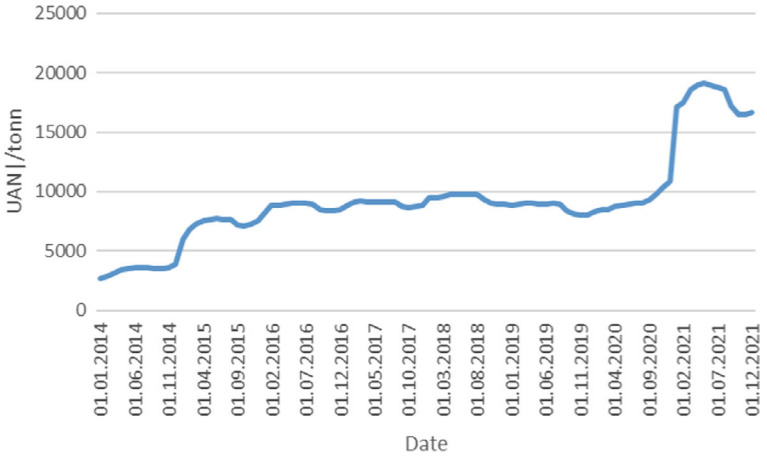

Fig. 4 Dynamics of the cost of sunflower during 2014–2021. *Source* Built by the authors based on [39]

trend. Possible reasons for this growth include the influence of climatic conditions, demand for corn for fodder, as well as global factors.

The price of sunflowers also increased during the study period. A significant price increase is observed from January 2014 (2711.7 UAH/t) to December 2021 (16,656 UAH/t). Reasons for this may include the demand for sunflower seed oil and the impact of global oil prices.

The price of pork from January 2014 (UAH 15,222.6/ton) to December 2021 (UAH 37,666.3/ton) also increased. This change may result from supply and demand

factors in the pork market and the influence of global trends in animal husbandry and meat production.

We will illustrate the construction of the VAR model using the example of the relationship between the prices of wheat, corn, sunflower, and pork, as well as the price of gasoline and the price of wheat in Europe. For the construction, prices were chosen according to the selected indicators for the period from 2014 to 2021 with a monthly interval. The data was taken from the website of the State Statistics Service of Ukraine [40] and from the official website of the General Directorate of Agriculture and Rural Development, "Monthly market prices" [41].

To build a model, first, we needed to check the all-time series for stationarity. For this, the extended Dickey–Fuller test was used.

In this case, it is possible to check each row separately or perhaps as a group. The first option was chosen, i.e., we tested each series for stationarity. The first step was to test each row in its original form. The results are given in Table 1.

As can be seen from the table of results, the value of the calculated value of McKinnon's τ-statistic is greater than the value of the critical value at 1, 5, and 10% levels of significance. In addition, the *p*-value (probability) of the test is > 5%. Therefore, the null hypothesis regarding the presence of a unit root in the time series cannot be rejected since the minimum probability that the series has a unit root and is not stationary is 88.38%, 50.09%, 55.43%, 65.21%, 63.70%, and 46.19%, respectively.

This means that the series in the levels are non-stationary. It is necessary to check whether it is possible to transform the series into stationary ones by operating the first differences. Therefore, conducting a similar Dickey–Fuller test is worth conducting, but already for series in first differences. The results are presented in Table 2.

The results of the Dickey–Fuller test for the series in the first differences indicate the stationarity of the transformed series. As can be seen, the magnitude of the calculated value of McKinnon's τ-statistic is smaller than that of the critical value at the 1, 5, and 10% significance levels. In addition, the *p*-value (probability) of the test is equal to 0.0000 (in the case of gasoline prices, 0.0007 and sunflower—0.0001).

Table 1 Dickey–Fuller test for checking the time series of product prices in levels for stationarity

Indicator/ variables	The price of wheat	The price of gasoline	The price of wheat in Europe	The price of corn	The price of sunflower	The price of pork
Calculated value	− 0.51	− 1.56	− 1.45	− 1.25	− 1.28	− 1.63
Critical value (1%)	− 3.51	− 3.50	− 2.50	− 3.50	− 3.50	− 3.50
Critical value (5%)	− 2.89	− 2.89	− 2.89	− 2.89	− 2.89	− 2.89
Critical value (10%)	− 2.58	− 2.58	− 2.58	− 2.28	− 2.58	− 2.58
Prob.	0.88	0.51	0.55	0.65	0.64	0.46

Table 2 The Dickey–Fuller test of the time series of product prices in first differences for stationarity

Indicator/ variables	The price of wheat	The price of gasoline	The price of wheat in Europe	The price of corn	The price of sunflower	The price of pork
Calculated value	− 5.96	− 4.34	− 9.13	− 6.41	− 4.88	− 9.66
Critical value (1%)	− 3.51	− 3.50	− 3.50	− 3.50	− 3.50	− 3.50
Critical value (5%)	− 2.89	− 2.89	− 2.89	− 2.89	− 2.89	− 2.89
Critical value (10%)	− 2.58	− 2.58	− 2.58	− 2.28	− 2.58	− 2.58
Prob.	0.00	0.0007	0.00	0.00	0.0001	0.00

This means that we reject the null hypothesis of the presence of a unit root (non-stationarity) in a series of first differences with minimal error (almost 0% of the time out of 100%).

It is also necessary to determine the number of lags for VAR models. The maximum lag test was used to define the optimal structure of the lags (Lag et al.). This test starts the estimation with some maximum number of lags in the model and then reduces it.

To begin with, we set the maximum number of lags at level 4 and gradually reduce it. The optimal length of the lag in this test is determined simultaneously by five standard information criteria—LR (sequential modified LR test statistic (each test at 5% level)), FPE (final prediction error), AIC (Akaike information criterion), SC (Schwarz information criterion), HQ (Hannan–Quinn information criterion). The results of the execution of the test are shown in Table 3.

The results calculations according to different informative criteria such as ratio logarithms functions likelihood (LR), final predictive error (FPE), criterion Akaike (AIC), Schwartz test (SC), and Hannan–Quinn (HQ) test show that the maximum number lags, the optimal model for inclusion in the VAR varies (in Table 3 this is indicated by the mark "*"). After analyzing the drawing, one can conclude that

Table 3 Results execution of the test to the maximum lag length of the VAR model

Lag	Log L	LR	FPE	AIC	SC	HQ
0	− 3886	NA	2.28e+2	85	85	85
1	− 3229	124	3.12e+23	71	72*	72
2	− 3175	93	2.11e+23	71	73	71*
3	− 3135	62*	2.01e+23*	70*	73	72
4	− 3111	35	2.70e+23	71	75	73

Table 4 Granger causality test between variables

Null hypothesis	Prob.
The price of gasoline does not affect the price of wheat	0.6490
The price of wheat in Europe does not affect the price of wheat	0.0510
The price of corn does not affect the price of wheat	0.0004
The price of sunflower does not affect the price of wheat	0.0144
The price of pork does not affect the price of wheat	0.3602

one must choose one lag model for the specification models, which shows the most informative criteria. For this case, this is lag 3.

The next step is to build the Var a Granger causality test performed on the model. This test is used to study the relationships between different time series, such as economic indicators, financial data, or any data that contains a time component. It helps determine whether information from one time series can be used to predict another time series. According to this test, the hypothesis of the absence of causal relationships is rejected if the probability is less than 0.05. The test results are given in Table 4.

According to the results, indicators such as the price of wheat in Europe, the price of corn, and the price of sunflower have an influence. Accordingly, the model was rebuilt, taking into account these three indicators. After building a model with the specified lags, it can be assumed that this specification best describes the relationships between the variables and has the best quality.

4 VAR Model and Food Prices Forecast in Ukraine

Equation models have such form as in formula (1). According to the built model, the current value of the wheat price is determined by its previous values in three periods, as well as the previous values of the European wheat price, corn price, and sunflower price with a three-period lag.

$$
\begin{cases}
price_{wheat} = 1.0539price_{wheat(t-1)} - 0.1925price_{wheat(t-2)} \\
\quad + 0.1073price_{wheat(t-3)} - 0.2340price_{sunflower(t-1)} \\
\quad + 0.2197price_{sunflower(t-2)} - 0.0111price_{sunflower(t-3)} \\
\quad - 0.6057price_{eu_{wheat}(t-1)} + 0.3283price_{eu_{wheat}(t-2)} \\
\quad + 0.0701price_{eu_{wheat}(t-3)} + 1.2989price_{corn(t-1)} \\
\quad - 1.5565price_{corn(t-2)} + 0.3711price_{corn(t-3)} + 564.9913 \\
price_{sunflower} = -0.2058price_{wheat(t-1)} + 0.8604price_{wheat(t-2)} \\
\quad - 0.0399price_{wheat(t-3)} + 0.9497price_{sunflower(t-1)} \\
\quad + 0.0755price_{sunflower(t-2)} + 0.0996price_{sunflower(t-3)} \\
\quad + 1.4092price_{eu_{wheat}(t-1)} - 4.8105price_{eu_{wheat}(t-2)} \\
\quad + 2.4472price_{eu_{wheat}(t-3)} + 0.3517price_{corn(t-1)} \\
\quad - 0.8495price_{corn(t-2)} - 0.5110price_{corn(t-3)} + 3080.231 \\
price_{eu_{wheat}} = 0.0254price_{wheat(t-1)} - 0.0260price_{wheat(t-2)} \\
\quad + 0.0230price_{wheat(t-3)} - 0.0165price_{sunflower(t-1)} \\
\quad + 0.0059price_{sunflower(t-2)} + 0.0290price_{sunflower(t-3)} \\
\quad + 1.30005price_{eu_{wheat}(t-1)} - 0.4260price_{eu_{wheat}(t-2)} \\
\quad - 0.0071price_{eu_{wheat}(t-3)} + 0.0653price_{corn(t-1)} \\
\quad + 0.0094price_{corn(t-2)} - 0.1360price_{corn(t-3)} + 351.9154 \\
price_{corn} = 0.0171price_{wheat(t-1)} + 0.0728price_{wheat(t-2)} \\
\quad + 0.0657price_{wheat(t-3)} - 0.0089price_{sunflower(t-1)} \\
\quad + 0.0483price_{sunflower(t-2)} + 0.0254price_{sunflower(t-3)} \\
\quad + 0.2880price_{eu_{wheat}(t-1)} - 1.1293price_{eu_{wheat}(t-2)} \\
\quad + 0.5523price_{eu_{wheat}(t-3)} + 1.1510price_{corn(t-1)} \\
\quad - 0.4321price_{corn(t-2)} - 0.0710price_{corn(t-3)} + 995.7540
\end{cases}
$$

where

$price_{wheat}$	is the price of wheat in the current year, UAH/t;
$price_{sunflower}$	the price of sunflower in the current year, UAH/t;
$price_{eu_{wheat}}$	the price of wheat in Europe in the current year, UAH/t;
$price_{corn}$	the price of corn in the current year, UAH/t;
$price_{wheat(t-i)}$	the price of wheat with the corresponding lag i (i = 1, 2, 3), UAH/t;
$price_{sunflower(t-i)}$	the price of sunflower with the corresponding lag i (i = 1, 2, 3), UAH/t;
$price_{eu_{wheat}(t-i)}$	the price of wheat in Europe with the corresponding lag i (i = 1, 2, 3), UAH/t;
$price_{corn(t-i)}$	the price of corn with the corresponding lag i (i = 1, 2, 3), UAH/t.

The determination ratio for the wheat price equation is 0.96, for the sunflower price equation—0.97, for the European wheat price equation—0.93, and the corn price equation is 0.98, i.e., almost all the variance of the relevant outcome variables was explained using regression equations.

The last step was to build a product price forecast based on the built model. The forecast results are shown in Figs. 5, 6, 7 and 8.

Based on an analysis of the developed VAR model for forecasting the price of wheat, we observe that, at the moment, the price of wheat has a downward trend without significant oscillations. The model confirms the stable nature of wheat prices in the period that covers the analysis. It is important to note that this model focuses on analyzing past data and does not include the influence of external factors such as global conflicts or other events that occurred in 2022, including war and other geopolitical events. Because this model is limited historical according to the data, it may be less sensitive to influence new events that happened after the completion of analysis. Additional monitoring and model updates can be valuable for more accurate predictions in unusual situations.

Stationary forecasting using VAR models may be impractical under market uncertainty, especially during the impact of war. Stationarity is a critical assumption in autoregressive modeling because it means that the statistical properties of a time series remain constant over time. However, in uncertain market conditions, the stability of statistical properties may be disrupted by sudden and unpredictable events such as geopolitical changes, economic sanctions, or the effects of war. This introduces a level of complexity that violates the stationarity assumption.

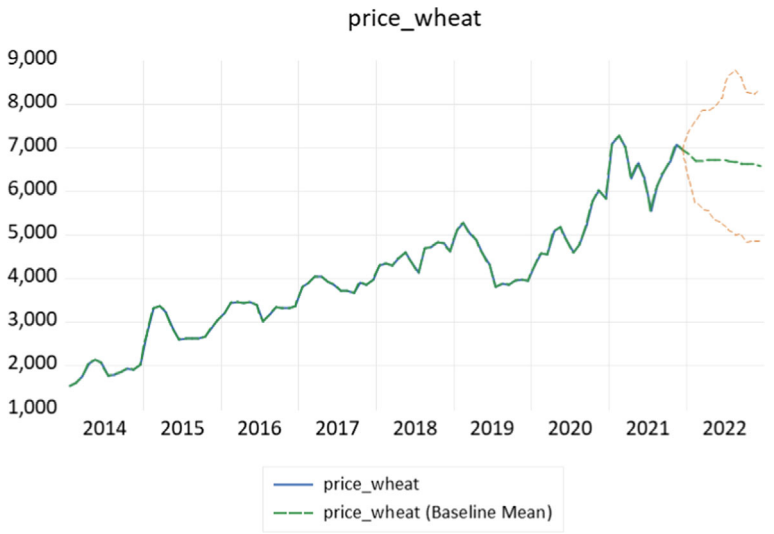

Fig. 5 Wheat price forecast for the input series based on the VAR model. *Source* Built by the authors

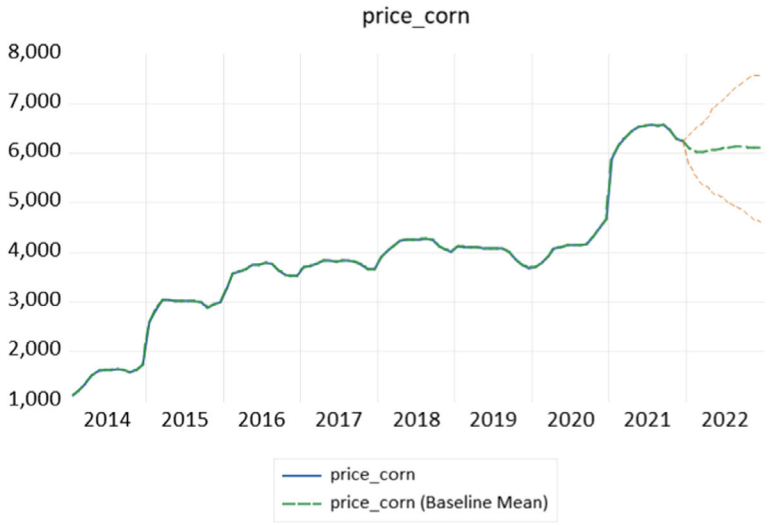

Fig. 6 Price forecast of corn for the input row based on the VAR model. *Source* Built by the authors

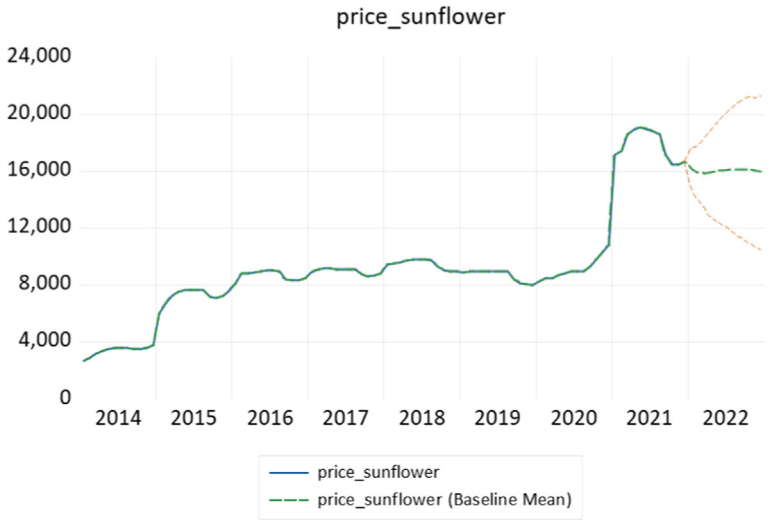

Fig. 7 Price forecast sunflower for the input row based on the VAR model. *Source* Built by the authors

Moreover, during times of war, markets often experience structural shifts beyond what traditional time series models such as ARIMA and VAR can capture. These models rely on historical patterns and relationships, assuming the future resembles the past. During the war, when unprecedented events and upheavals can occur, these models may find it challenging to adapt and make accurate predictions.

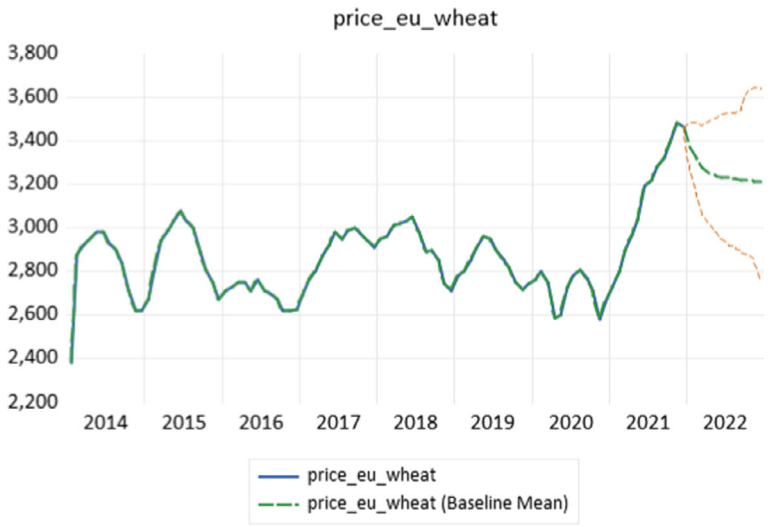

Fig. 8 Wheat price forecast in Europe for the input series based on the VAR model. *Source* Built by the authors

Forecasting using VAR models is not appropriate during market uncertainty, especially during times of war, due to their limitations in handling the non-linearities, structural shifts, and unprecedented events that characterize such turbulent times. Alternative modeling approaches, potentially including machine learning techniques or adaptive models, may be better suited to capture the subtleties of volatile markets.

5 Summary and Conclusion

In this investigation, a Vector Autoregressive (VAR) model was employed to forecast food prices in Ukraine. The analysis leveraged data spanning from January 2014 to December 2021 and encompassed wheat, corn, sunflower, pork, gasoline prices, and European wheat prices. The model successfully identified a positive trend in the prices of these food commodities over the studied period. Subsequently, a VAR model with a three-lag structure was constructed to capture the interconnectedness between these price variables. This model achieved a high degree of explanatory power, as evidenced by the determination coefficients exceeding 0.93. Based on this model, a downward trend with limited volatility was forecasted for wheat prices. However, the study acknowledges limitations inherent to the VAR model. The model's dependence on the assumption of stationarity renders it less effective during periods of significant market uncertainty, particularly those characterized by war. Additionally, the model's exclusion of external factors, specifically the 2022 war and its ongoing geopolitical consequences, potentially compromises the accuracy of its predictions. In conclusion,

while the VAR model provides valuable insights into historical food price trends in Ukraine, its limitations in handling non-linearities and unforeseen events necessitate the exploration of alternative forecasting approaches. Machine learning techniques, for instance, might be better suited to capture the complexities of volatile markets and enhance prediction accuracy during periods of heightened market uncertainty.

Data Availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request. **Funding Statement** The study was supported by the National Scholarship Programme of the Slovak Republic at the SPECTRA Centre of Excellence of the EU at the Slovak University of Technology in Bratislava.

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Cooperation Between EU and EaP Countries in the Development of E-Services for Citizens

Oleh Tsebenko, Olha Ivasechko, Yaryna Turchyn, and Ivan Bratus

Abstract The article examines the peculiarities of cooperation between the EU and the Eastern Partnership countries in developing e-services for citizens. The key challenges to developing digital services in the region are analyzed. By analyzing the data of global indices in digitalization, the levels of development of digital services in the Eastern Partnership countries are studied. The strengths and weaknesses of cooperation between the EU and the EaP countries in the development of digital technologies are highlighted using SWOT analysis. The main areas of collaboration and EU support for digitalizing the region's states are highlighted. The PESTLE analysis helped to identify the specifics of the impact of various factors on the digitalization and implementation of e-services in the region. A classification of the EaP countries by the level of e-services implementation was developed. A comparative analysis of the implemented e-services in the studied countries and the EU support tools for introducing digital technologies was conducted. The key areas of cooperation between the EU and the EaP countries in the digital sphere are identified. Scenarios for strengthening cooperation between the EU and the region's countries in the digital sphere are proposed. It is concluded that the EU plays a key role in the digitalization of the Eastern Partnership countries. Thanks to this, the region's states have significantly progressed in implementing e-services for their citizens. By integrating into the EU's Digital Single Market, the EaP states will be able to achieve significant success in implementing digital technologies for their citizens.

Keywords E-services · EU · Eastern Partnership countries · Cooperation · Digitalization

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1 Introduction

In the twenty-first century, the development of digital technologies is the key to the successful functioning of the state and its economic and social development. The digital revolution has covered all spheres of human activity. The EU and its member states are the most digitized in the world today. The EU's digital policy is also aimed at external countries and is one of its priorities. The EU understands that successful and digitized neighboring states are the key to sustainable functioning. The Eastern Partnership region is an area of interest for EU foreign policy. The countries of the region, which includes five states: Ukraine, Georgia, the Republic of Moldova, Armenia, and Azerbaijan (Belarus ceased its participation in the EU's Eastern Partnership Initiative in 2021, so it will not be the subject of our study) are heavily burdened by a difficult Soviet past, low levels of economic development, and digitalization. It is the strengthening of cooperation between the EU and these states in 2009, when the new policy of the EU's Eastern Partnership Initiative was launched that has become a certain driver of change and reform. The main goal of the EU is to bring the EaP states closer to European standards and strengthen their economy, energy, democracy, and governance. One of the priorities of their cooperation is digital technologies and the development of digital services in the field of public administration, healthcare, and services for the population. For the EaP countries, implementing digital standards is an important step towards European integration and a key to the successful development of society. The EU has several mechanisms to support digital technologies, including financial instruments, targeted programs, technology provision, and exchange of experience.

The development of digital technologies will contribute to democracy, better participation of the population in government processes, and reduction of corruption. The EaP countries continue to implement digital technologies intensively, so cooperation with the EU will be the basis for further development.

2 Related Works

Digitalization and the development of digital technologies are extremely interesting for modern science. Very little scientific literature is devoted to studying cooperation between the EU and the Eastern Partnership countries in digital technologies. The main source base for the study was scientific articles, statistics, global indices, and online resources.

A group of Ukrainian researchers, including Oleh Tsebenko, Olga Ivasechko, Yaryna Turchyn, and Roman Holoschuk, is studying the development of digital technologies. Their research reveals the peculiarities of integrating the digital markets of the EaP countries into the EU single market and cooperation between the EU and these countries in the field of e-business [1–3].

Kisting examines the prospects for developing digital technologies in Europe and analyzes their current trends. Akhvlediani's study highlights the problems and features of digital literacy among the Eastern Partnership countries' populations [4, 5].

Dimitrova, Mazepus, Boroda, Chulitskaya, Berbeca, Parvan, and Manners studied the peculiarities of the EU's influence on the EaP states through normative, soft, or transformative power [6, 7].

Data from global indices, including the E-participation Index, the Network Readiness Index, the Digital Quality of Life Index, the Online Service Index, and the Human Capital Index, also served as a source base [8, 9].

We also analyzed the websites of the European Commission, the EU Eastern Partnership Initiative, and EU4Business [10–12].

3 Research Methodology

The methodological basis of this study was some general scientific and special research methods. In particular, the comparative analysis helped to compare the positions of the EaP countries in global indices, showing their level of digitalization. The study also compared the availability of e-services for the population in different countries and EU instruments to support digital transformation in the region.

We also applied the SWOT analysis method, which helped us identify the strengths of digitalization in the EaP countries, identify key issues that hinder the introduction of e-services in the region, explore the prospects for strengthening cooperation between the EU and the EaP countries in the introduction of digital services for the population, and predict potential challenges that could hinder such collaboration.

We used the PESTLE analysis method to identify political, economic, social, technical, legal, and environmental achievements and challenges in implementing e-services in cooperation between the EU and Eastern Partnership countries.

The analysis of global indices, including the E-participation Index, Network Readiness Index, Digital Quality of Life Index, Online Service Index, and Human Capital Index, helped determine the Eastern Partnership countries' level of digitalization and their populations' access to digital technologies and resources.

Using the prognostic method, scenarios were developed to develop cooperation between the EU and the Eastern Partnership countries in e-services implementation. The case study method analyzed individual countries' e-services implementation examples. The institutional method was used to analyze EU instruments to influence the EaP countries in supporting the development of digital services for the population. The generalization method helped to formulate recommendations and conclusions to the study.

Analyzing the EU's transformative, normative, and soft power also served as a methodological basis. With the help of these powers, the EU is trying to integrate the Eastern Partnership states into its fold. We can also distinguish the EU's digital power, which is realized through the EU Digital Compass, from integration into

the EU single market, which involves integrating the region's states and adopting appropriate regulations [4, 7, 13].

4 Results

The priority areas of cooperation between the EU and the Eastern Partnership countries in the E-services sphere are:

1. Development of digital infrastructure;
2. Maximum access of the population to the Internet;
3. Development of E-governance;
4. Development of digital infrastructure;
5. Implementation of digital technologies in the economy [14];
6. Cybersecurity and personal data protection [15];
7. Digital literacy for the population [16];
8. Development of e-health [17] and e-education [18, 19];
9. Harmonization of legislation in the digital sphere with European standards;
10. Cross-border cooperation in digitalization [1, 20, 21].

The key mechanisms for the implementation of the EU E-services in the Eastern Partnership countries are:

1. The EU Eastern Partnership initiative;
2. The EU4Digital and EU4Business targeted programs;
3. EU financial support instruments;
4. EU candidate status for Ukraine, Georgia and Moldova;
5. Integration of states into the digital single market;
6. EU Neighborhood Policy;
7. Cross-border projects [22];
8. Bilateral cooperation between the EU and each of the Eastern Partnership countries;
9. Exchange of experience in digital services with states [2, 3, 23, 24].

Table 1 presents internal and external challenges for implementing E-services in Eastern Partnership countries [2, 24].

Figures 1 and 2 depict a SWOT analysis of the EU's cooperation with Eastern Partnership (EaP) countries in the field of urban services for the population.

Figures 3 and 4 present the PESTLE analysis of EU cooperation with the CAP countries in the field of public services.

To determine the level of digital services implementation in the EaP countries (see Fig. 5), we analyzed several global indices that helped us determine the overall level of digitalization.

We analyzed the Network Readiness Index for 2023. The index analyzes the degree of readiness of a country to use digital opportunities. According to the data analysis in Fig. 6, Ukraine is the most ready. Azerbaijan and Georgia are the worst

Table 1 Internal and external challenges for E-services implementation in Eastern Partnership countries [2, 24]

Internal challenges	External challenges
1. Weak development of digital technologies 2. Authoritarian system of government in some countries 3. Low level of economic development of the states 4. Low level of digital literacy of the population 5. Lack of specialists in the digital sphere 6. Weak digital infrastructure and low internet connectivity in the EaP countries 7. Weak level of personal data protection 8. Weak system of cyber defense and counteraction to cybercrime [25, 26] 9. Low level of financial resources to support digitalization reforms 10. Outdated technologies in the digital sphere 11. Lack of desire among government officials to integrate into the EU 12. Bureaucratic and corruption obstacles to the implementation of digitalization reforms	1. International cybercrime 2. Low intensity of integration into the EU 3. Geopolitical challenges in the Eastern Partnership region 4. The Russian-Ukrainian war and frozen conflicts in the region 5. Hybrid warfare and Russian information propaganda against the EU 6. Global challenges to humanity 7. The global digital divide between countries

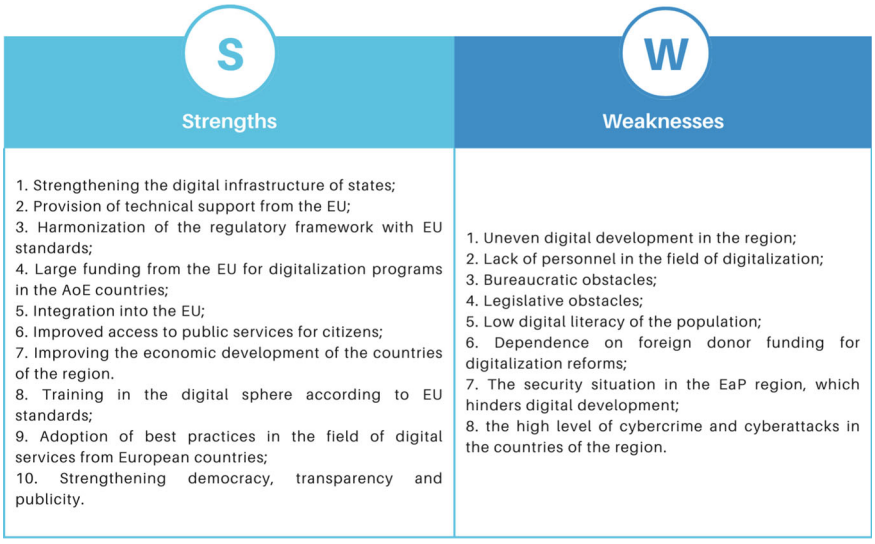

Fig. 1 SWOT analysis of the EU's cooperation with the EaP countries in the field of u-services for the population (part 1)

Fig. 2 SWOT analysis of the EU's cooperation with the EaP countries in the field of u-services for the population (part 2)

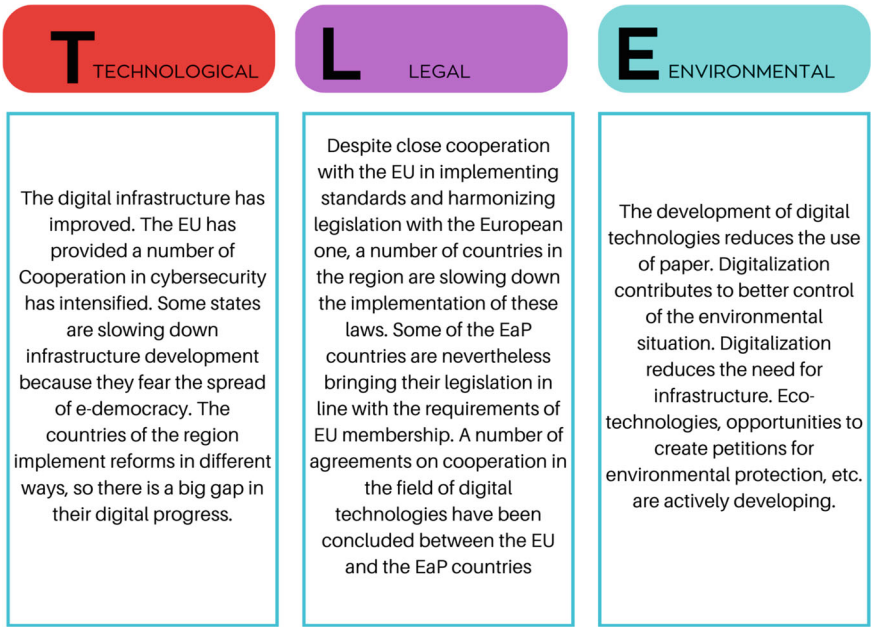

Fig. 3 PESTLE-analysis of EU cooperation with the CAP countries in the field of public services (part 1)

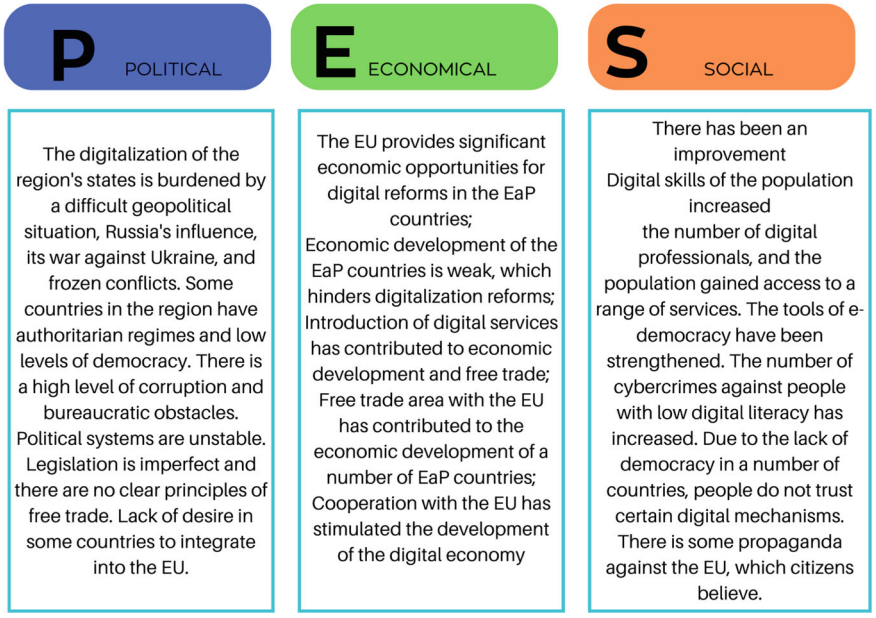

Fig. 4 PESTLE-analysis of EU cooperation with the CAP countries in the field of public services (part 2)

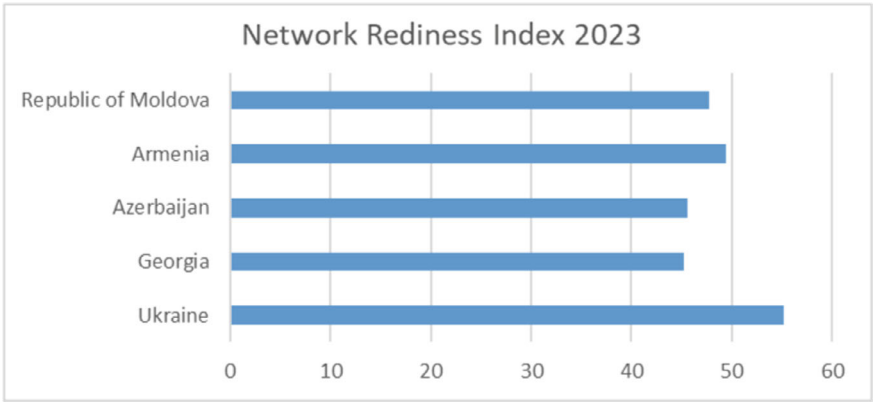

Fig. 5 Network Readiness Index 2023 [9]

performers. In general, the Eastern Partnership countries are in the middle of the pack regarding this indicator and need to improve their digital performance. Cooperation with the EU will significantly strengthen the digital resilience of these countries.

The Digital Quality of Life Index shows the level of Internet quality, Internet access, digital security, digital infrastructure, and e-government in a country.

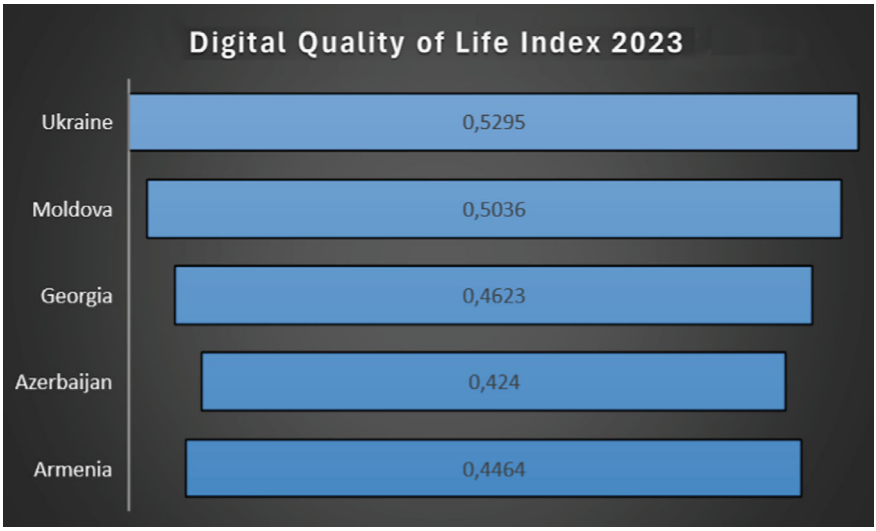

Fig. 6 Digital Quality of Life Index 2023 [8]

Analyzing this index allows us to determine the level of access to digital services for citizens of the Eastern Partnership countries. Ukraine and Moldova have the highest scores. Georgia, Azerbaijan, and Armenia have slightly lower scores. However, all EaP countries have an average value in relation to the best performers in this Index, so they need to strengthen digitalization reforms.

The E-participation Index data indicates online access to information (see Fig. 7), opportunities for online consultation, and online decision-making. Moldova is the highest in this indicator. Ukraine, Georgia, and Armenia are somewhat worse. Azerbaijan's score is much worse, due to the lack of democracy in the country. The countries of the EaP region need to be significantly strengthened in this indicator.

The Online Service Index measures the government's (see Fig. 8) ability and willingness to provide online services and communicate with its citizens through online resources. According to this indicator, Ukraine is in the best position, while Georgia and Azerbaijan are in the worst position.

The E-Government Development Index data indicates the level of development of e-government (see Fig. 9), opportunities for online communication between the public and the authorities, and the availability of public online services. Ukraine has made the most progress in this indicator among the Eastern Partnership countries. Moldova, Georgia, and Armenia have roughly the same score. Azerbaijan's position in this indicator is the weakest, due to its political system and lack of a democratic regime.

The Telecommunication Infrastructure Index data indicate the state of development of information and communication technologies (see Fig. 10). Ukraine and Georgia have the best positions in this indicator, while Moldova is somewhat behind.

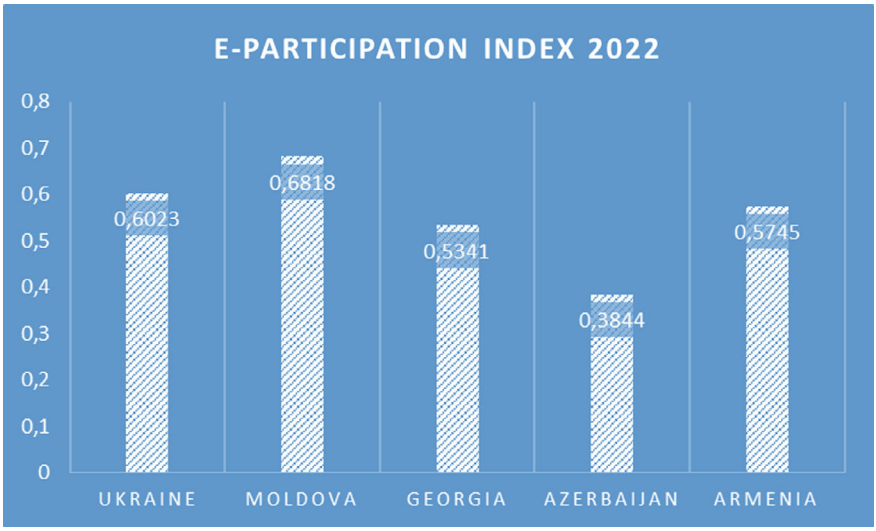

Fig. 7 E-participation Index 2022 [9]

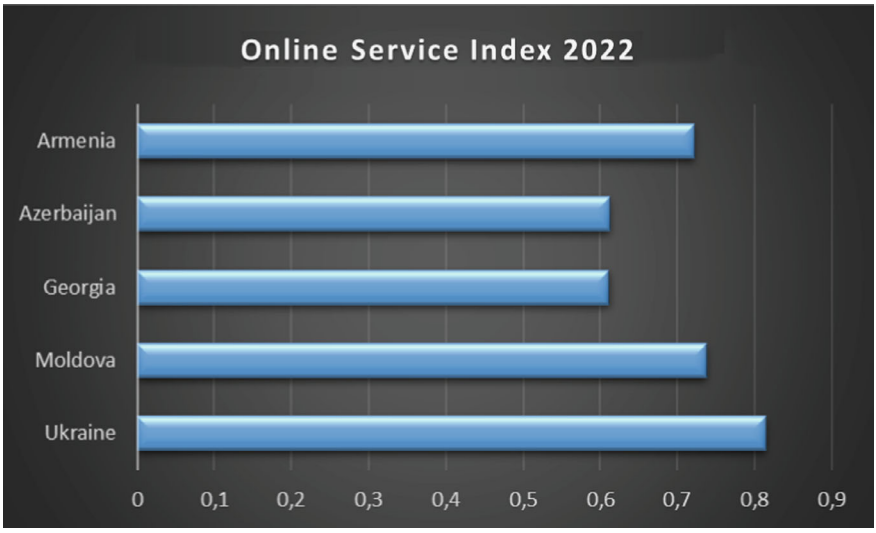

Fig. 8 Online Service Index 2022 [9]

A comparative analysis of the EaP countries' performance in the five digitalization indices (see Table 2) suggests that Ukraine has the best access to digital resources for its population. The Republic of Moldova also has a fairly good position in these indicators. The situation is somewhat worse in Georgia and Armenia. Azerbaijan has

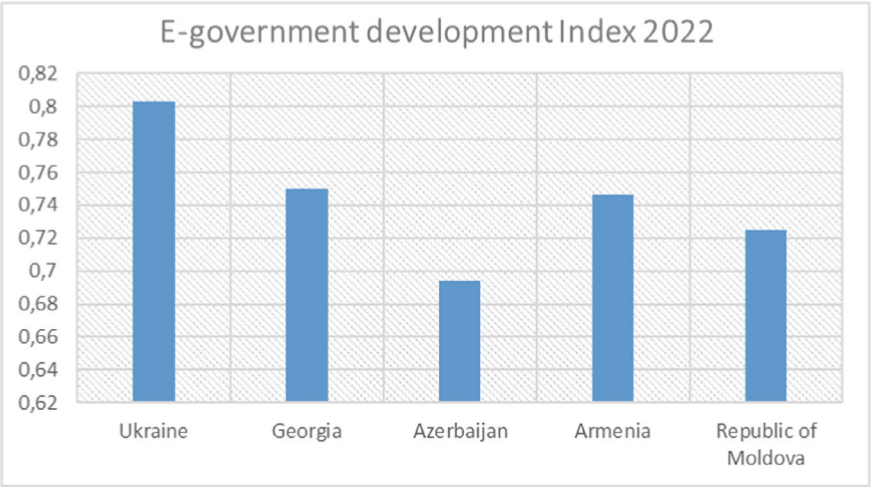

Fig. 9 E-government Development Index 2022 [27]

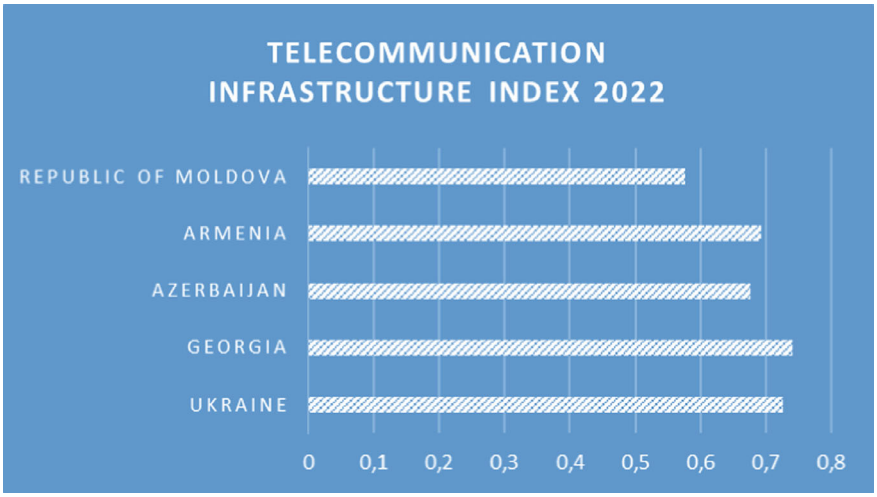

Fig. 10 Telecommunication Infrastructure Index 2022 [9]

the lowest scores due to the state rule regime. All EaP countries generally have close to average scores and need significant digitalization reforms.

The comparative table on the availability of e-services in the Eastern Partnership countries shows that Ukraine has made the most progress in digital services for the population (see Table 3). Moldova and Georgia are somewhat worse off, as they are still on the path to digitalization. The success of these three countries depends on their cooperation with the EU in the digital sphere and European integration.

Table 2 Comparison of the EaP countries' performance in global indices in digitalization [8, 9, 27]

Country	E-government Development Index	Network Readiness Index	Digital Quality of Life Index	E-participation Index	Online Service Index	Telecommunication Infrastructure Index
Ukraine	0.8029	55.16	0.5295	0.6023	0.8148	0.727
Moldova	0.7251	47.69	0.5036	0.6818	0.738	0.576
Georgia	0.7501	45.25	0.4623	0.5341	0.6111	0.7409
Azerbaijan	0.6937	45.57	0.424	0.3844	0.6119	0.6761
Armenia	0.7464	49.36	0.4464	0.5745	0.7221	0.6925

Table 3 Availability of E-services in EaP countries [1, 2, 5, 11, 13, 24, 28–30]

Country	E-democracy	E-governance	E-health	E-business	E-education	E-banking
Ukraine	+	+	+	+	+	+
Moldova	+	+	±	+	±	+
Georgia	±	±	+	+	+	+
Azerbaijan	−	−	±	±	±	±
Armenia	±	±	±	±	±	±

The situation in Armenia and Azerbaijan is somewhat worse. This is due to authoritarian regimes, low levels of democracy, and Russia's significant influence on these countries. Strengthening the EU's influence in these countries could improve the situation by introducing digital technologies for the population in the Eastern Partnership countries.

Table 4 analysis shows that support for digitalization in the EaP countries is uneven according to various criteria. This stems from the EU's policy of supporting states that are more eager to integrate and implement reforms. The Associated Trio states, which already have candidate status and are seeking EU membership, have much more support for digital reforms. Azerbaijan and Armenia are more restrained in implementing European digital legislation and standards, so their support is somewhat lower. However, the EEU tries to pay attention to all states in the region in the implementation of digital technologies.

The EU supports the following recommendations for strengthening E-services for citizens in the Eastern Partnership countries: [1, 2, 5, 12, 20, 28, 31].

- Accelerate the adoption of the necessary legislation, reforms and European standards in the digital sphere;
- Intensification of the use of best European practices in the field of digital services for the population;
- Strengthening EU financial and grant support for the implementation of digital technologies in the Eastern Partnership countries;

Table 4 Comparative analysis of EU instruments to support the digitalization of the EaP countries [1, 2, 5, 6]

Country	Financial support	Technical support	Digital reform support	Digital program	Cybersecurity support	Institutional support
Ukraine	+	+	+	+	+	+
Moldova	+	+	+	+	+	+
Georgia	±	+	+	+	+	+
Azerbaijan	±	±	±	+	−	±
Armenia	±	±	±	+	−	±

- Strengthening the training of digital specialists in accordance with European standards;
- Integration of the Eastern Partnership countries into the EU's digital single market;
- Active participation of the region's states in EU programs and initiatives implemented within the framework of the EU's Eastern Partnership Initiative;
- Formation of educational programs in higher education institutions of the EaP countries to train specialists in the field of digital technologies;
- Strengthening digital literacy activities among the population in the Eastern Partnership countries;
- EU support for the cyber resilience of the Eastern Partnership countries.

Scenario: To predict the prospects for the development of cooperation between the EU and the Eastern Partnership countries in the area of e-services for the population, we present several possible scenarios:

- Scenario 1: Some EaP countries (Ukraine, Moldova, and Georgia) integrate into the EU and its digital market—the most likely scenario in the medium term;
- Scenario 2: All EaP countries integrate into the European digital space and implement digitalization reforms—an unlikely scenario in the short and medium term, but in the long term, given the growing influence of the EU and the US in the region, this option is highly likely;
- Scenario 3: The development of digital technologies is slowed down in the Eastern Partnership countries. As a result of the authorities' lack of interest in European integration and digitalization, and Russia's growing influence on the region's states, there may be no progress in introducing digital technologies to the population, an unlikely scenario;
- Scenario 4: The EaP countries will increase the adoption of digital technologies and implement digital reform without integration into the EU, but in close cooperation. The states with authoritarian regimes (Armenia and Azerbaijan) will limit the digitalization of governance and democracy, which is a highly probable option in the short term.

5 Conclusion

To summarize, implementing e-services for the population is an important area of sustainable development of the state. The Eastern Partnership region is a priority for the EU. One of the areas of cooperation is digital [32–36]. The EEU cooperates with the region's countries within the EU Eastern Partnership Initiative framework, the EU Neighborhood Policy, and EU4Business programs. The introduction of digital technologies in the region's countries faces many internal and external challenges, including authoritarian regimes, the decline of democracy, corruption, a difficult geopolitical situation, and Russia's influence on the region's countries. Analyzing the situation with the introduction of digital technologies has shown that cooperation with the EU has significant positive effects. In particular, there has been an improvement in the development of digital infrastructure, expanding public access to the Internet, training in the digital sphere, and increased harmonization of legislation with EU standards. The analysis of global digitalization indices showed that Ukraine has the best situation with introducing digital technologies. Moldova and Georgia are somewhat worse off. This is undoubtedly due to increased integration into the EU. Armenia and Azerbaijan have somewhat worse indicators. This is because they have an authoritarian system of government and a low level of democracy, and Russia has a significant influence on their political system. The EU uses several tools to support the digitalization of the EaP countries (financial, political, technical). Still, different countries perceive the importance of this cooperation differently, so this support is greater for the Associated Trio countries. The EU should strengthen the integration of the region's states into the EU, provide more technology and financial support, and support reforms. The most likely scenario is that Ukraine, Moldova, and Georgia will integrate into the EU's Digital Single Market and continue implementing digital services with EU support. At the same time, Armenia and Azerbaijan will not sufficiently incorporate into the European digital space in the short to medium term.

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Educational Innovations in the Formation of Professional Linguistic and Communicative Competence of a Manager in Conditions of Crisis Challenges

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Abstract The article offers a model of using modern innovative interactive methods and methods of active learning in higher education institutions, which encourage future managers to educational and cognitive activity and allow creating an atmosphere of motivated, creative learning and at the same time solving a complex of cognitive, educational, and developmental tasks. The model has been tested in teaching humanitarian disciplines in higher educational institutions of Ukraine of technical and economic profile. The factors of growth of the role of educational innovations in the conditions of crisis challenges, when there is a need for distance online learning, are allocated. Characterized of innovative approaches and features of the use of interactive methods in the teaching of language and humanities in the modern education system. It is emphasized that achieving the goal is possible due to the successful combination of traditional and innovative teaching technologies, since innovative technologies are diversifying and significantly enriching the teaching of disciplines, while traditional work is complemented by intellectual creative search, during which a new type of manager is formed—a creative personality: active

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and purposeful, focused on constant self-education and development. It is found that one of the main advantages of interactive methods is the approximation of the learning process to the real practical activities of future specialists. Interactive methods contribute to the formation of professional linguistic and communicative competence of the manager in the conditions of intensification and optimization of the educational process, stimulate the active involvement of the student in the educational process, allow solving problems in interaction and communication, teach them to correctly formulate their opinion; analyze the received information; discuss, argue their position; think creatively, be more confident and independent.

Keywords Distance learning · Manager · Services · Platforms · Innovative learning technologies · Interactive methods · Professional linguistic and communicative competence · Crisis challenges

1 Introduction

During the orientation of higher school to the development of the creative personality of a professional, of particular importance is the formation of professional linguistic and communicative competence of the manager, which is possible provided that the content of training is organically connected with the chosen profession and modernization of the content of Ukrainian language courses (by professional orientation), rhetoric, the basics of terminology in other language and humanitarian disciplines for applicants of relevant specialties, taking into account the specific principles and methods of training in the face of the challenges of our time.

New living conditions are associated with the intensive development of science and technology and constant crises that require deep rethinking, original solutions, and a positive projection for the future, which require creating new technologies, updating educational programs, and using interactive teaching methods. Since education is an important element in this process, then, accordingly, it should prepare a specialist of a new generation—creative, who would be able to combine the experience of the past and the present for the benefit of society and be responsible for the future; ready to work in critical conditions and learn throughout life; has cognitive flexibility, logical thinking, etc.

Considering the above, each institution of higher education develops innovative teaching methods to ensure that the educational process meets the practical needs of modern student managers and contributes to the quality training of future specialists. During the quarantine, hostilities, and active migration processes, interactive distance learning methods become popular and demanded, based on purposeful and controlled intensive independent work of a higher education applicant who can study in a convenient place, according to an agreed schedule upon with teachers and under the guidance of experienced teachers-mentors without visiting the university, online. In extreme conditions, the role and importance of distance learning and the use of modern information innovative technologies is growing, which implies “the creation

of an educational environment focused on meeting the needs and interests of applicants for higher education, in particular, providing opportunities for the formation of an individual educational trajectory" [1].

Distance learning, introduced by order of the Ministry of Education and Science of Ukraine in connection with the introduction of all-Ukrainian quarantine, hostilities, and migration processes, continues today, as the emergency does not end. Therefore, distance learning is one of the new realities of modern education in the difficult conditions of crisis challenges with a projection on the renewal of the directions of professional and pedagogical communication. The concepts of "personality-oriented communication of the teacher," "emotionally supportive communication of the teacher," and "inclusive communication" are actualized in the works of Sukhenko [2], Cheremska et al. [3], Khoma et al. [4]. The article is aimed at analyzing and generalizing innovative approaches and features of using the interactive methodology in the formation of professional linguistic and communicative competence in the modern educational system, which is designed to guarantee and maintain a safe, creative learning environment that can intensify the system dialogue with applicants using digital platforms; creation, justification, and verification of the model for introducing innovations in education in modern crisis conditions.

2 Literature Review

The development of the educational environment of the innovation-active university is lighted in the works of such scientists: Barz et al. [5] Luzyawati et al. [6], Han et al. [7], Tashev et al. [8], Rodriguez et al. [9], Kuan et al. [10], Handa et al. [11], Bayne and Ross [12], Barabash et al. [13]. The use of interactive teaching methods is explored in the writings of Lee et al. [14], Cheremska et al. [3], Khoma et al. [4]. Multimedia systems as a means of interactive learning are considered in studies by Désiron et al. [15], Mahajan et al. [16], Omri and Fkih [17], and Wu [18].

Studies of the innovative strategy of modern education are lighted in the works of both domestic and foreign scientists [19]. According to Dubasenyuk, "This is a complex process that involves the gradual updating and improvement of content, methods, tools, pedagogical technologies, which, of course, affects the quality of the pedagogical process" [17]. However, the issue of effective application of innovative education methods, especially in conditions of crisis challenges, remains relevant. In particular, the issue of interactive teaching methods in the realities of the present is analyzed in the works of such scientists as Hrastinski, Livingston et al. [19], Abdulrazzaq et al. [20], Ambiyar et al. [21], Morgan [22], Cavanaugh et al. [23], Abdul Lasi [24] and others.

Among the learning models, scientists distinguish traditional or classical, active, and interactive. The dynamics of innovative teaching methods can be traced through scientific, pedagogical, and methodological works. Many scientific studies are devoted to this topic, in which attention is focused on the theoretical foundations of innovative methods, their classification, and the effectiveness of use [25, 26].

It should be noted that the researchers of the problems of pedagogical innovation correlate the understanding of the new in the educational process with the following characteristics: useful, progressive, positive, modern, and advanced [27].

SMART technologies are becoming a priority today, a powerful tool for acquiring and assimilating knowledge. Exploring modern active methods of learning in higher education, foreign sources focus on the latest technologies: blending learning, BYOD (Bring Your Own Device), flipped classroom, and event-based learning. These technologies also include technologies for developing critical thinking, scenario-based learning, design technologies, case study technology, etc. [28].

3 Materials and Methods

To achieve this goal, a set of theoretical and empirical research methods is used in the work. The following theoretical methods are applied: analysis of scientific sources on the topic to determine the state of research on the problem of introducing educational innovations in conditions of crisis challenges; synthesis, comparison, systematization—to generalize theoretical approaches to the need to apply educational innovations in higher education; abstract-logical method—to generalize key concepts and formulate conclusions; modeling—to create a model for introducing innovations in education in modern crisis conditions. Several empirical methods were used: observation, assessment, and self-assessment—to determine the level of need for the use of educational innovations in institutions of higher education, a descriptive method for characterizing various innovative pedagogical technologies, methods of systematization and classification for grouping innovations in the development of communicative competence of higher education applicants in modern crisis conditions into a five-block model.

4 Results and Discussion

At the beginning of the XXI century, the pedagogical problem was the limited possibilities of traditional education in institutions of higher and pre-higher education. These restrictions have repeatedly intensified the work to ensure the continuity of the educational process and the involvement of new forms and methods of education. Among the most important tasks facing the educational process today, scientists note "the ability to work out new methods of teaching and education, are based on the curriculum and learning method organized according to learning theories, and the ability to prepare and develop an appropriate creative learning environment, which facilitates and improves learning and teaching processes, providing them with an interactive side and the right investment in their use and presentation" [29].

The development of technologies such as YouTube, Twitter, Facebook, cloud technologies, distance learning, blogs, Google, etc., makes education accessible.

SMART-education in higher education is an application for educational purposes of smartphones, tablets, interactive whiteboards—smartboards, and other devices with access to the Internet, as well as various educational programs and applications. A significant achievement of the modern educational process is the development and improvement of an integrated intellectual virtual environment for learning with educational content in order to form a future specialist—a creative personality. For instance, Lviv Polytechnic for many years practices a Virtual learning environment based on Moodle; his work over the past 5 years has intensified and today all academic disciplines are provided with educational and methodological content for studying the material and gaining skills and practical work.

It was the introduction of innovative pedagogical technologies and methods into the educational process of educational institutions that made it possible to modernize the educational sphere. Among the newest methods with the use of modern information and communication technologies (shown in Fig. 1), we distinguish, in particular, the following methods: online dialogues and discussions (using video conferencing, applicants for education under the guidance of a teacher can discuss topics, ask questions and exchange opinions in real time); virtual laboratories (enabling experiments and research in secure virtual environments); game technologies (allow you to be interested in learning, making it creative and dynamic and bringing the learning process as close as possible to the realities of professional life); collaborative projects of video presentation (contribute to gaining experience in teamwork on joint projects, develop communication and interaction skills at a distance); interactive videos, intellectual competition-quizzes (video materials with built-in tests and tasks are an effective tool for checking the level of assimilation of material and improving the theoretical knowledge base of students), etc.

Innovations predict new forms of organization of activity and management, and new types of technologies that embrace various spheres of human life. The main goal of innovation is to optimize and increase the efficiency of the educational process and create an educational environment that will satisfy the needs of applicants for education [30].

Given this, the harmonious formation of the creative cognitive activity of the teacher is possible provided when the appropriate pedagogical conditions are met: the acceptance of individuality as a given, introduction of pedagogical stimulation of differentiated cognitive activity, priority use of modern interactive teaching methods [25, 26]. Distance learning requires a new approach from the teacher to the preparation and conduct of training sessions. These sessions have characteristics, the most important of which is to adapt to a virtual meeting rather than a real one. It is not easy to adapt to distance learning, but the latest methods allow the teacher to unobtrusively and creatively conduct the educational process and feel the benefits of modern technological achievements.

In pedagogy, the term “innovation” (lat.—change, introduction of a new one) means novelty, renewal of the learning process: “the process of creating, introducing and disseminating new ideas, tools, pedagogical and managerial technologies in educational practice, as a result of which the indicators (levels) of achievements of

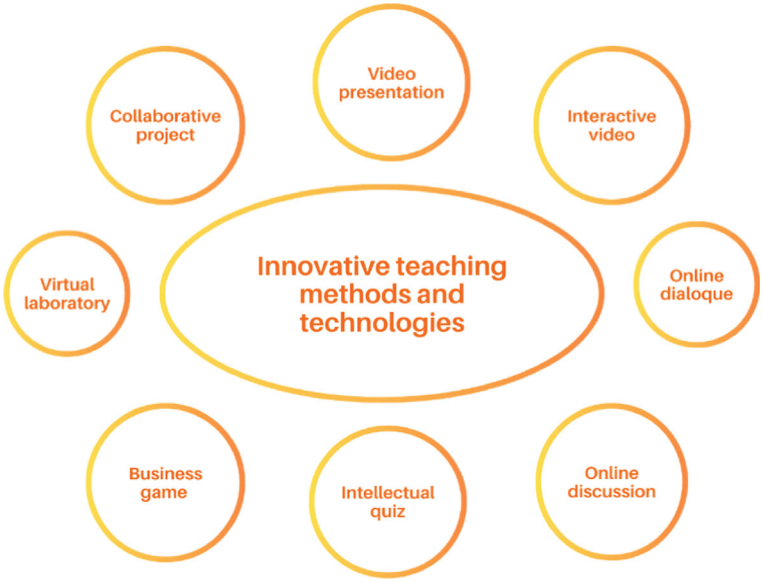

Fig. 1 Innovative teaching methods and technologies

the structural components of education are increasing, the system changes to a qualitatively different state" [31]. The complex concept of "innovation" contains two components: the actual idea and the process of its practical implementation. Scientists of the International Institute for Systems Research, compilers of the dictionary "Innovative Glossary", determine the essence of innovation through the categories of novelty and progressiveness: innovation is a kind or result of the development process [32]. However, real innovation, compared to innovation and renovation, means more than replacing old elements with new ones in a separate system. According to the authors, the new is only such an element or system that is more progressive than the old, which means their compliance with the positive trend of the development process as a whole. The statement of the fact that innovation is possible only if the criteria of novelty and progressiveness of a new element or system are used.

Pedagogical innovation is the process of creating, distributing, and using new tools to solve those pedagogical problems, the ways of solving which are outdated. Pedagogical innovations are aimed at overcoming the crisis in education caused by global challenges, by improving the quality of the educational process, giving the educational process a personality-oriented, humanistic character, and in a broad sense—the formation of a harmoniously developed, innovative-thinking, and socially adapted linguistic personality.

Innovative methods are methods that imply an increase in the role of the subject in the educational process, a shift in the focus of the educational process from the teacher to the applicant for education; strengthening the function of its support, assistance in organizing an individual educational process; possibility of teacher feedback with

each applicant in the process of using educational technologies and information and communication technologies.

Scientists emphasize the essence and importance of innovation in the educational process. As Pometun notes, innovation is "the process of creating, distributing and using new tools (innovations) to solve those pedagogical problems that still were solved differently" [33]. The use of innovative methods in the teaching process began in the twentieth century and gained popularity in the last decade due to the rapid development of information and communication technologies. Innovative technologies make it possible to move from studying an abstract subject to perceiving it as a means of communication and thinking and to bring educational and cognitive activity to a modern, creative level. The introduction of innovative methods significantly improves the quality of presentation of educational material and the effectiveness of its assimilation by applicants for education, enriches the content of the educational process, increases motivation to study the discipline, and creates conditions for closer partnership between teachers and applicants for education. Such a partnership is a guarantee that the teacher becomes a mentor not only during the study of the academic discipline but also in everyday practical communication. Therefore, the use of innovative methods is extremely important in the learning process.

Innovative technologies, according to the observations of Dychkivska [34], contains two groups of approaches to the teaching of languages, namely:

(1) interactive teaching methods;
(2) use of technical training tools (computer and multimedia, Internet) to control knowledge, storage, and use of training materials.

Information society with the development of information and communication technologies was transformed into SMART-society, which led to the creation and use of SMART-technologies in the educational process, and, accordingly, to increase the level of motivation of applicants for education to study. Smart technologies in the educational process dynamically update the content, forms, and methods of teaching [35].

Scientific and pedagogical workers note that education today can exist only if technical means are used. This is a unique experience for methodologists and teachers. Modern information technologies in higher education are considered one of the types of technologies that involve the use of not only computer equipment but also organizational and communication components to activate the educational process and modernize various forms of education. For example, with the introduction of distance learning, educational institutions began to use the *technology of a webinar*, that is, a "virtual" seminar organized using Internet technologies. It has all the advantages of a traditional seminar, except for the possibility of "backstage" communication between visitors, as well as "live" communication between them and the speaker. These are perhaps the only significant drawbacks of webinars. Advantages, in our opinion, much more: the cost of organizing webinars is significantly lower; accessibility for "visiting" listeners is very high; significant savings in organization time; convenience for "visitors"; interactive interaction between the speaker and "visitors", as well as "visitors" among themselves. With the help of Internet technologies, the

webinar has preserved the main feature of the lesson—interactivity, which provides modeling of the functions of the speaker, the listener, who will work interactively, communicating according to the scenario of such a lesson.

Communicative competence is one of the most important qualities of a modern specialist manager, to the understanding of which, in the conditions of modernization of the educational process, interest increases significantly. Communicative competence in the study of linguistic and humanitarian disciplines is defined not only as the ability to grammatically correctly, accurately, logically, clearly, expressly formulate and express one's thoughts but also the ability and skills to apply language at all its levels based on stylistic expressiveness, communicative expediency, by the tasks and situation of communication, exerting an influence on the interlocutor, creating a linguistic image of his professional and social role. Graphically, the components of communicative/competence are shown in Fig. 2.

It is on the improvement of communicative competence that the educational process is aimed at studying the disciplines of the linguistic and humanitarian direction. He has the task of developing practical language skills as a means of communication in a variety of professional situations, depending on the purpose of communication. Based on the communicative competence of the linguistic personality, we form professional linguistic and communicative competence, which implies the availability of professional knowledge, as well as other key competencies [3]; conversation and communication skills. We provide professional language education taking into account the needs of the specific subject competence of the relevant

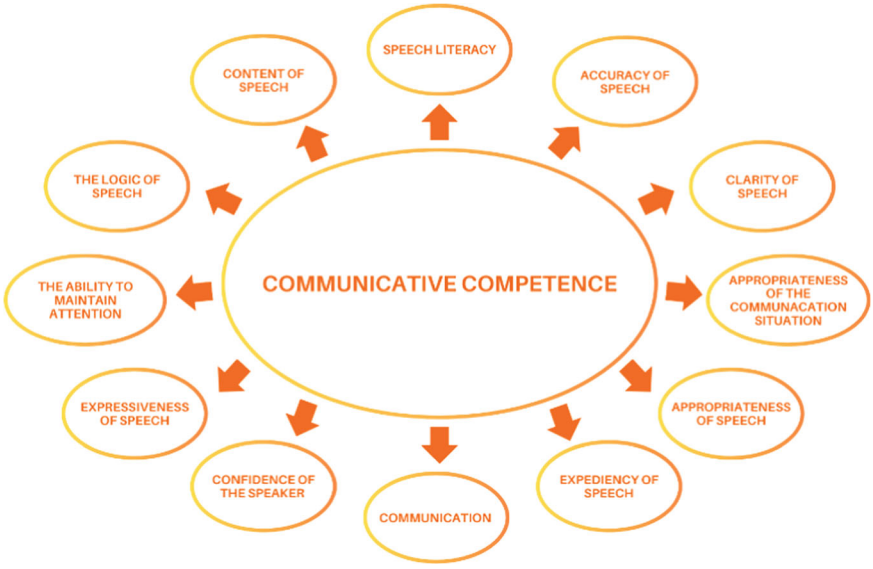

Fig. 2 Components of communicative competence

industry standards and requirements that modern society imposes on an international specialist.

In today's situation of crisis challenges, the issue of the formation of professional language-communicative competence using online Internet technologies is relevant. For learning-related tasks, two online communication formats are used: webinar (or online seminar) and webcast (web conference). These formats differ in the degree of interactivity: in the webinar, as in a regular seminar, there is an opportunity to interact with the lecturer—to perform his tasks, answer questions, and ask your own. At the web conference, the speaker speaks most of the time. After the event, a record remains, which can also be used for training purposes; in fact, it is a finished product.

During the webinar, it is appropriate to use the techniques of illustration and demonstration using interactive comparison tables, algorithms, presentations, videos, etc. Note that the method of programmed learning is also effective, which activates the mental-cognitive activity of students, guarantees constant feedback and the algorithmic study of the material provides a logical sequence of students performing mental operations and individualizes the educational process [36].

Determination of the content of the programs of language and humanitarian disciplines and the selection of teaching methods are carried out taking into account the specifics of training in an institution of higher education and the current situation. Monitoring of communicative needs of applicants for the education of economic specialties of Simon Kuznets Kharkiv National University of Economics, Lviv Polytechnic National University, Kharkiv National Automobile and Highway University, for example, made it possible to determine specific approaches to the creation of educational materials on language disciplines that take into account the specifics of the specialty and the scientific interests of future specialists.

In modern didactics, creatively using traditional general pedagogical principles, they take into account the specific (actually methodological) principles of teaching humanitarian disciplines. The category of "principles of learning" is constantly changing and updating—views on the theoretical foundations of learning are transformed, and new principles appear. Basing the educational process on the general principles of science, accessibility, consistency and consistency, continuity and perspective, visibility and interconnection of the material and intellectual components of the educational environment, cooperation, and community, it is, in our opinion, skillfully combines them with the specific principles of teaching language disciplines, in particular with the principle of creativity.

The principle of creativity in the classroom is realized through the creation of a creative environment, the components of which are a creative personality, a creative process, and a creative product. Creativity is spontaneity, and self-perception, which allows a person to fully realize his potential.

We consider an artful person as a creative person who, as a result of the influence of external factors, has acquired necessary for actualization the creative potential of a person additional motives, personal formations, and abilities that are contributing to the achievement of creative results in one or more types of creative activity. Creativity is a common personality property that manifests itself during the creative process as the ability to generate a diverse socially important original product and productive

ways of its application; the ability to find solutions in non-standard situations; a property that is realized only under favorable environmental conditions at a high level in various fields of human activity throughout life. Formation of the creative personality of the manager under the force of a broad humanitarian education in all types of educational institutions. Humanitarian knowledge lays the philosophical foundations of the worldview, and democratic beliefs, and educates morality and high spirituality, which is the basis of the creative personality.

In the creative environment of teaching linguistic disciplines, we distinguish such varieties of the creative process as the actual disciplinary creative process, which involves the direct study of linguistic and humanitarian disciplines in classroom classes and the independent mastering of individual topics and the use of original explanations of linguistic phenomena, the presence of alternative interpretations of texts, the use of active, interactive and innovative teaching methods (for example, work in an electronic environment, entertainment technologies, etc.).

An integral organic component of modern education is the formation of linguistic, communicative, and professional competencies of applicants for education in the process of creative learning. This is an innovative process designed to ensure the successful professional activity of a creative specialist and his competitiveness in the labor market. The achievement of communicative competence and professional linguistic and communicative competence is ensured by systematic work, which involves the development of the optimal content of the program in rhetoric and other disciplines, and the application of active, interactive, and innovative methods. In the process of studying in high school, we distinguish three closely related stages of activity:

(1) communication skills (mastering the laws of communication and the features of interpersonal communication);
(2) professional language communication skills (understanding of professional text and discourse and mastering the conceptual and categorical apparatus of a separate professional sphere and the corresponding system of terms);
(3) the development of creative thinking (the production of new ideas, the use of non-standard ways of solving problems, making innovative decisions) (see Fig. 3).

Fig. 3 Steps of training activities

Innovative transformations in the modern educational space cause important changes, giving rise to new teaching methods, expanding the educational and information base, and diversifying educational resources. The active development of globalization and the modernization of the education system taking place in Ukraine put forward new requirements for the training of specialists, the key for which is the combination of theory and practice. Today, the education system is aimed at educating initiative members of society who can effectively interact in solving social, industrial, and economic problems.

Socio-economic factors contribute to the actualization of innovative processes in the field of education. The innovativeness of active teaching methods lies in the conscious perception by the pedagogical as a whole of the processes of memorizing educational material by applicants for education, in its practical implementation.

In the context of the crisis challenges of our time, the formation of professional linguistic and communicative competence of a creative person is facilitated by such forms, methods, and techniques as creating a situation of "scientific discoveries", an atmosphere of success and trust in the process of communication; a sense of moral satisfaction of the applicant for education from communication activities, independent search and research work, the creation of a bank of professional texts for linguistic analysis; conducting a discussion based on life experience, etc.

The procedure of choosing teaching methods in the process of teaching language and humanities disciplines involves certain stages. First, it is necessary to predict the most rational combination of teaching methods according to the source and logic of learning information, and the level of cognitive activity of education applicants. After that, it is important to choose methods of stimulation that would ensure the formation of cognitive interest in the outlined topic. In addition, it is necessary to take into account the time of the lesson, to determine the stages at which it is advisable to apply methods of control and self-control.

Features of the traditional (classical) model are that applicants for education learn the material from the words of the teacher (traditional lecture) or the text of the textbook without participating in the discussion of the problem. Active model—involves stimulating cognitive activity and independence of applicants, interaction in the system of applicant-teacher, as well as the presence of creative tasks.

Interactive model—the process of interaction between the teacher and the applicant for education, the use of modeling life and professional situations, role-playing games, and methods that allow you to create situations of search, empathy, contradictions, doubt, conviction, analysis, and self-assessment of your actions, joint problem-solving.

The interactive lesson involves organizing the educational process in such a way that various types of tasks (dialogues, monologues, discussions, games), forms of training (pair, group work, less often independent), work with various sources of information (audio and video materials, magazines, newspapers, etc.) are involved [37].

It's important that teacher must create a comfortable psychological atmosphere and conditions for learning, adjust and direct the activities of applicants for education through cooperation with them. The most famous methods of interactive learning are

the case method, project method, role-playing and business games, training sessions, team contest, and competitions. Also actively used elements and techniques of interactive learning in traditional forms of higher education—work in pairs, work in small, working or creative groups, brainstorming, etc.

A modern teacher is always in search of innovative teaching methods that would contribute to an interesting and rapid assimilation of the material. In our opinion, the most important components of this process are interactive teaching methods and technical means. It should be noted that while studying the humanities, the frequent interactive teaching methods are the project method, brainstorming, exchange of partners, forced debates, rotation in groups, intellectual map, method of play, and others. A generalized characterization of these methods is presented in Table 1.

The project method assumes that the applicant for education independently plans, creates, and protects his project, that is, actively participates in the process. An educational project is a complex of search, research, calculation, graphic, and other types of work that applicants perform independently in order to practically or theoretically solve a certain problem. The project method helps to develop language, speech and intellectual abilities, interest in studying humanities, and the need for self-education. The result involves the achievement of communicative competence, that is, a certain level of language, country studies, socio-cultural knowledge, communication skills, and speech skills that make communication possible. The method of projects makes it possible to realize not only educational tasks but also socio-cultural, educational, tasks of humanizing the educational process.

Role-playing and business games occupy an important place in the development of communicative competence. They are used as a means of increasing the motivation of applicants for education to study. There are various typologies of role-playing and business games. By content, they are divided into socio-domestic and professional. By the nature of the interaction between applicants and the teacher—on controlled, moderately controlled, scenario, and free. By duration, role-playing and business games can be short and long. An interesting interactive method of learning is a business game as a form of modeling the conditions and relations of professional activity, characteristic of a particular type of practice, which contributes to the development of professional skills, forms the ability to interact with partners, business qualities and traits of future specialists, causes positive emotions, stimulates mental activity, develops non-standard thinking. The use of game methods contributes to active controlled purposeful communication, satisfaction of the desire for group forms of interaction, and has developmental potential.

The method of specific situations case-study is the solution of cases, and problem situations; significantly activates communication activities. Incidents which are offered for discussion by the teacher should be related to real-life situations. They serve applicants education specific material for reflection, and ideas. The method (case-study) represents a special method of training, which consists in using specific cases (situations, stories) for joint analysis, discussion, or development of decisions by applicants in a certain section of the academic discipline. Working with “cases” involves analyzing situations or solving specific problems according to a certain

Table 1 The essence and practical value of interactive teaching methods

No.	Method name	Method essence	Practical value
1	Method of projects	Set of training-cognitive techniques that allow you to achieve a specific training objective as a result of independent actions of student with mandatory presentation of received results	Stimulates interest of students to certain problems, the solution of which assumes possession of a certain amount of knowledge, skills and abilities; implements balance between academic knowledge and pragmatic skills
2	Role-playing and business games	Modeling situations predicting the same limitations, motivations that exist in the real world	Contribute to strengthening personal involvement in everything that occurs
3	Method of specific case-study situations	Using descriptions of real economic, social and business situations that their students should investigate, and having understood the essence of the problem offer possible solutions and choose the best of them	Teach to communicate for compatible search optimal solutions
4	Brainstorming	Group expression of any ideas for searching solutions for the certain problem; all offers are first recorded, and only then are analyzed for creating new solutions out of format of template thinking	Develops critical thinking, activates mental activity and creative activity of the future specialist
5	Research method	Organization of cognitive student activities through creative studies of certain problems involving independent scientific search	Promotes deep assimilation of material course and enables master statistical, interpretive and other methods of scientific research
6	Socratic dialogue	Formation of planned dialogue in the form of short questions and answers, it leads to positive answers to important questions	Teaches to avoid unnecessary disputes, take the initiative, forms logical thinking
7	Decision tree	Description of decision-making procedure with certain question that occurs as a result of the implementation of a certain situation	Allows you to understand mechanisms of adoption of complex solutions, teaches analyze contradictory data
8	Public performance	Oral monologue statements on a certain theme to achieve a certain impact on audience (inform, persuade, agitate, call to action)	Forms a holistic image of a speaker who absorbs linguistic and non-linguistic aspects of communication
9	Master class	Improvement classes of practical skill, that conducted by specialist of a particular field for developing certain skills	Allows you to achieve skill in a certain type of practical activity

scenario, which covers both the independent work of the applicant and "brainstorming" within a small group, and public speaking with the presentation and defense of the proposed solution.

One of the most effective technologies of group interaction, which has special opportunities in the training, development, and education of the future specialist, is a discussion. The teacher forms small groups of students who discuss the problem issue and after a fixed time present one or more of his decisions that were formed by the applicants for education during the discussion. The following forms of discussion became widespread in the world pedagogical experience: round table, "relay", expert group meeting ("panel discussion"), forum, symposium, debate, and brainstorming. The combination of various types of discussion in the pedagogical arsenal of the teacher allows you to make the learning process interesting, and rich for educational applicants not only with new discoveries in the discipline that is studied, in the profession and life, but also with the discovery of new things in yourself and others.

We also offer to refer to such innovative teaching methods while working with applicants for higher education, as the analysis of errors, collisions, incidents; audiovisual teaching method; dialogue of Socrates (Socrates dialogue); "decision tree"; discussion with the invitation of specialists; "take a position"; commenting, evaluating (or self-evaluating) the actions of participants; master classes; method of analysis and diagnosis of the situation; modeling; PRES-formula (from the English Position—Reason—Explanation or Example—Summary); problem (problem-search) method; public speaking; Work in small groups; individual and group trainings (both individual and complex skills), etc.

Research is an important method of work associated with developing creative thinking. It involves the organization of students' cognitive activity through creative research of certain problems that involve an independent scientific search. For example, when studying the course "Fundamentals of Terminology" it involves independent processing of texts to choose from, to assert the skills and abilities to analyze semantic modifications of terminal units of different levels of determination. Students choose texts for research according to their preferences, carry out a continuous selection of quotes from them with the facts of determination, classify them according to thematic characteristics, the levels of determination, etc. The latest information technologies enable students to facilitate work on the selection of research materials. So, you can choose quotes in which scientific terms of various branches of knowledge are used using the General Regionally Annotated Corpus of the Ukrainian Language (GRAC). Statistical and corpus methods of research attract the special attention of students, as they allow you to automate the painstaking work of finding materials for research work. Today, text corpuses are widely used in both linguistic and non-linguistic fields [38, 39]. This work contributes not only to the assimilation of the course material but also allows to master statistical, interpretive, and other methods of scientific research.

Acquire the skills and abilities of public speaking and achieve mastery in communication—this is one of the most important tasks of a professional manager. Therefore, an important method of training is to prepare and deliver speeches on various topics in order to achieve a certain impact on the audience: to inform, convince,

Fig. 4 Interactive teaching methods

agitate, encourage certain actions, and entertain. Speeches to the audience, in particular, during practical classes on rhetoric, can be devoted to discussing topical issues arising from program topics, as well as raising interesting in modern socio-political conditions of the problem. Actual topics for educational speeches of students, which can also predict polar thoughts, can, for example, be: "How to achieve self-confidence?", "Culture of the speaker's speech: components of success", "Does everyone need a higher education today?", "Virtual environment today: useful or harmful", "The problem of emigration in Ukraine: support or oppose", ""I do not" want to—worse than "can't"?" and others (Fig. 4).

The modern stage of existence and development of the world community is characterized by an increase in the rate of aging of information in various spheres of human activity, as well as an increase in the rate of integration processes in many fields of knowledge. Such circumstances, of course, cause the need to form a willingness to acquire, restore, and expand knowledge, significantly changing the nature of the pedagogical activity itself.

All the above methods are relevant, because they can be used in the educational process using services and platforms for distance learning, for example Moodle (allows you to create high-quality training courses; contains a powerful testing device and a variety of training elements; enables differentiated learning; can use wide pedagogical scenarios and educational strategies (programming, modular, individual, social learning); has options to control user access to the course; tracking the progress of education applicants through visualization; the ability to publish educational content of various formats—audio, video, text, etc.), the Edmodo Web app (positioning itself as Facebook for learning, built on the principle of social educational networks), the Google Classroom platform (allows you to create your own course; organize the recording of applicants for education on the course; provide the necessary training material, tasks; evaluate the work of applicants and monitor their progress; organize communication), Zoom (one of the popular app that provides

video and audio communication with each participant in the educational process, recording a video conference; allows you to show the screen with sound; has an interactive board); Skype (the functionality of the program provides everything necessary for conducting remote classes: screen demonstration; Recording the conversation in the cloud sending files), etc. It is worth noting that it was in a crisis situation that teachers had an urgent need to master new forms and methods and actively apply them to ensure the flexible organization of the work of the educational institution, setting up a comfortable, educational process. During this period, special attention was paid to the forms of personality-oriented, emotionally supportive, and inclusive communication of the teacher with education applicants, which made it possible to reduce the stress threshold and motivate them to live fully and ensured the achievement of the emotional and value community of the teacher and the applicant for education.

For the introduction of distance learning methods in the educational process, the long-term coordinated creative activity of the team and a solid foundation, a tool that can provide constant access to services and platforms, are important. S. Kuznets Kharkiv National Economic University has a unique experience in distance learning using innovative methods. The personal, educational system is an information and educational environment used during classroom and extracurricular independent work. The purpose of the introduction of a personal, educational system long before the crisis challenges was precisely to ensure the quality of education by meaningfully filling the educational environment, ensuring equal access of participants in the educational process to high-quality educational and methodological materials, regardless of their place of residence and form of education, creating conditions for personalizing learning, using information and communication technologies.

Since March 2019, Ukrainian universities have been paying constant attention to improving the quality of educational services and introducing modern innovative methods of traditional and interactive learning using interactive methods and various audio-visual programs (Skype and Webex, video conferences based on the Zoom platform, as well as Viber, YouTube, Telegram, Instagram, etc.). During the first crisis call, an asynchronous mode of interaction between remote learning subjects was tested, in which participants interact with each other with a time delay. Subsequently, a synchronous mode was gradually introduced, which provides simultaneous interaction between distance learning subjects that are in an electronic educational environment and communicate using audio and video conferencing tools.

Today, institutions of higher and pre-higher education have organized the educational process in accordance with the individual needs and capabilities of each student based on the introduction of an adaptive learning trajectory in modern distance or online learning systems built using adaptive methods and models. There is a three-level model of personal training systems: content level—interactive level—autonomous level. The development of online courses is carried out at the following stages: planning the process of studying the discipline as a set of interrelated types of educational activities of applicants for education; formulation of expected learning outcomes from the course and their correlation with the goals of the relevant educational programs; evaluation of achievements of expected learning outcomes; plan

topics and activities for the entire course, where each element has a direct relationship with the expected learning outcomes.

Seven online courses of interactive level with the following components have been developed from the Ukrainian language (according to the professional direction): visual materials, evaluation log, electronic testing, multi-level tasks, communication tools, incoming and outgoing testing, current monitoring of attendance, and success. Their advantage, like online learning in general, is interactive and test tasks (multiple choice); flexibility of access to training materials, automated assessment, providing instant feedback, which can be combined with formative tests that improve the quality of training; online forums for mutual support and discussion. Five-year testing, the activity of the education applicants, and the monitoring of the work of teachers by means of feedback (educational discipline through the eyes of the applicant) demonstrated the effectiveness of using online courses aimed at improving the skills and abilities of communication in the educational and scientific, socio-everyday, socio-cultural, official and business spheres of communication; mastering forms of speech etiquette in the process of various activities; development of the ability to work with scientific text, other sources of information; improvement of skills of interpretation of information.

The advantages of S. Kuznets PES (personal educational system) KhNEU today are the reduction of unproductive labor costs of the teacher; free choice of education trajectory by the applicant; continuous feedback in the learning process; efficiency and objectivity of control and evaluation of learning outcomes; individualization of educational activities; differentiated approach to applicants for education; to increase motivation.

Significant attention should be paid to the issues of working with applicants with limited educational needs, and the identification of peculiarities of development which are key factors affecting educational activities, professional orientation, life position, and personality formation. The task of Institution of higher education (IHE) teachers is to educate a vitally competent, competitively capable graduate.

In a difficult historical period, it is important to constantly work on improving the system of educational services for people with special educational needs. A modern lesson, built with taking into account inclusive learning, requires rethinking the priorities of individual methods, techniques, and types of educational activities, in particular with the involvement of those who form the skills of interpersonal interaction, work in a group, the ability to perform various social roles in a team. For the development of general and special abilities of applicants for higher education (regardless of the chosen specialty), preference should be given to pedagogical systems providing for lectures of various types (Socratic (problem), discussion); didactic heuristics—a type of training in which all the main educational elements are primarily created or found by the applicants themselves; interactive learning technologies, the essence of which is that all applicants for higher education are involved in the educational process, exchanging knowledge, ideas, ways of activity; a suggestopedic educational system, which is characterized by pseudo-passivity of behavior regarding the learning process, the applicant's internal mood for learning; productive training based on the

principles of practical life experience. Important for applicants with limited educational needs are creative teaching methods that are focused on creating their own educational products and in the traditional sense are intuitive: a method of inventing (a way of creating a previously unknown rule or concept based on the results of their mental actions); the method of the figurative picture (reproduces such a state of the applicant, when the perception and understanding of the studied material, as if merging, occurs its integral, unexplored vision); the method of hyperbolization (implies exaggeration; increases or decreases the object of knowledge, its individual parts or qualities); synectic method (this is a way of stimulating the imagination of applicants through a combination of heterogeneous concepts, which is based on the association); method of inversion (appeal) (focused on the search for ideas in new, unexpected directions, mostly opposite to traditional views and beliefs; its characteristic features are the orientation towards the development of the dialectic of thinking of applicants, creative abilities and communication) [2].

The study of ways of introducing innovations in developing communicative competence of higher education applicants in modern crisis conditions is based on a five-block model (Fig. 2), which has practical importance for all participants in the educational process. The graphic highlights the interrelatedness and interdependencies of each of the model blocks (Fig. 5).

The model by all features is systemic since it corresponds to the generally recognized provisions of the theory of systems: purposefulness, complexity, divisibility, integrity, and structuring. The systemic-making component of this model is the goal, which is to optimize and increase the level of efficiency of the learning process aimed at developing the communicative competence of higher education applicants in conditions of quarantine, hostilities, and forced migration. The defined goal involves the implementation of leading tasks: ensuring the continuity of the educational process in crisis conditions; modernization of the educational environment; and activation of innovative and creative potential of higher education applicants.

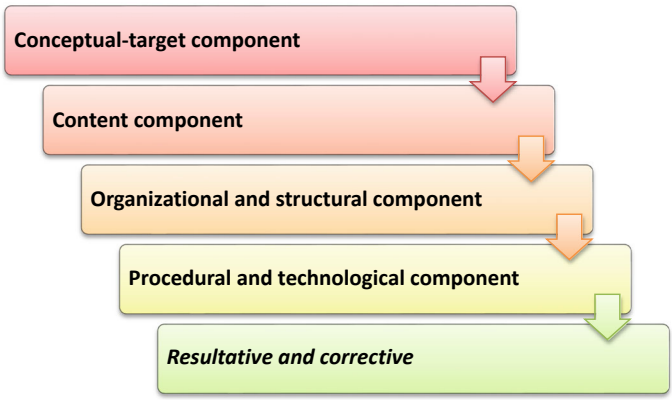

Fig. 5 Model of innovation in education in modern crisis conditions

The model is characterized by a set of interdependent and mutually agreed organizational, scientific, scientific and methodological approaches and procedures. It is based on conceptual and target, content, organizational and structural, procedural and technological, effective and corrective components that have bilateral ties with each other.

The *conceptual-target component* of the developed model covers the principles, patterns, and scientific approaches to the introduction of innovations in education in modern crisis conditions (Fig. 6).

The *content component contains* an analysis of innovative methods, techniques, and technologies aimed at improving the learning process and overcoming educational losses in emergencies, and tools that contribute to the modernization of the educational process (Fig. 7).

The *organizational and structural component* of the model assumes the influence of subjects on the objects of implementation of innovative educational technologies during quarantine, hostilities, forced migration, and the conditions for the application

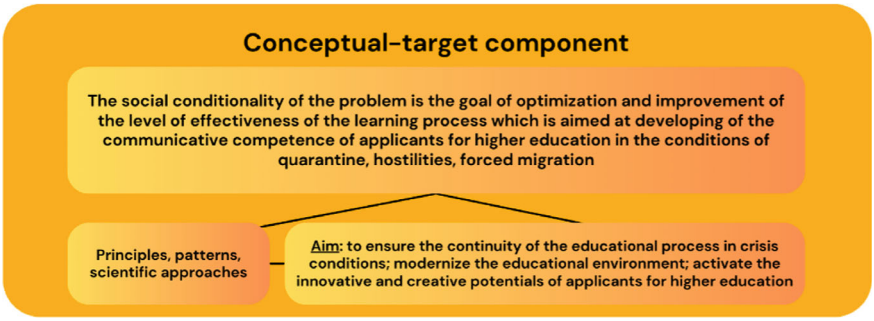

Fig. 6 Conceptual-target component model

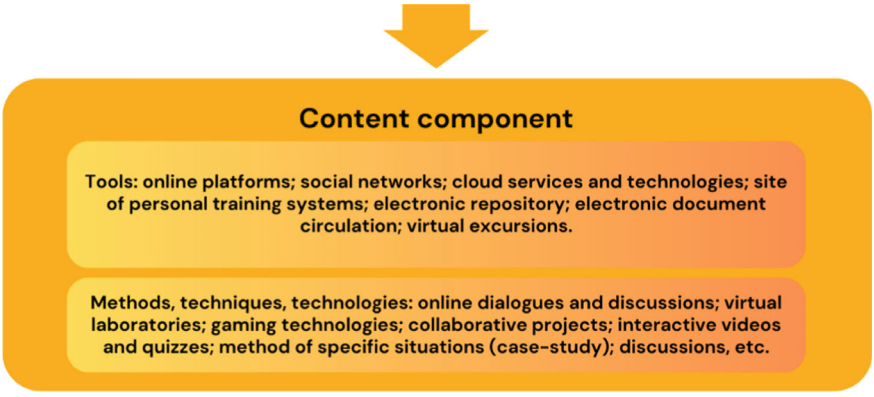

Fig. 7 Content component model

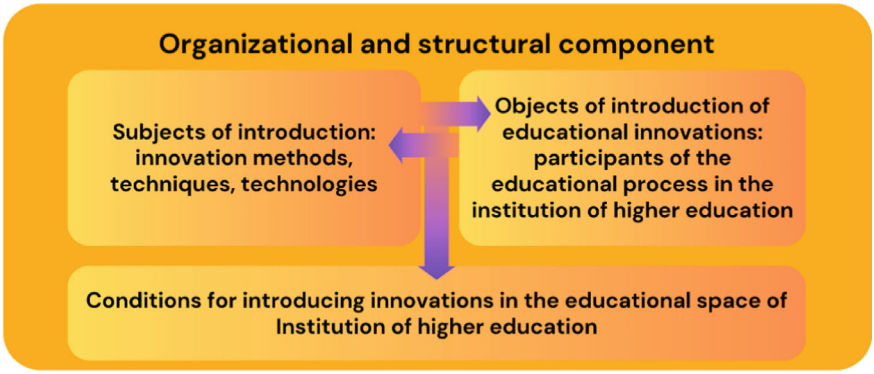

Fig. 8 Organizational and structural component model

of innovations in the educational space of the Institution of higher education (IHE) (Fig. 8).

The *procedural and technological component* of the model contains the corresponding technology for introducing educational innovations, namely: generalization of the experience of using modern innovative methods and methods of active training in higher education (on the example of Simon Kuznets Kharkiv National University of Economics); clarifying the role of educational innovation during online learning; determination of criteria and indicators of innovation in education; organization of the learning process on the basis of planning and designing new approaches to the preparation and conduct of training sessions using educational innovations; assessment, analysis of the feasibility of active use of innovations based on the results of training and regulation of the educational process using modern innovative methods (Fig. 9).

The *resultative and corrective component* provides for the analysis of the obtained result of the innovation activity of Institution of higher education (IHE) teachers aimed at developing the communicative competence of education applicants, the formation of the future professional, and the construction of a corrective trajectory of a systematic approach to the introduction of educational innovations in Institution of higher education (IHE) in crisis conditions. The model was tested in the process of teaching humanities at the Semen Kuznets Kharkiv National Economic University. The results of testing the developed model of introduction of innovations in education in the current crisis conditions prove that the model promotes self-monitoring of the level of teaching aimed at the formation of the future professional, teaches self-analysis, and forms the ability of Institution of higher education (IHE) teachers to consciously manage their professional activities using innovative technologies and teaches them to create a trajectory of their self-education and self-improvement regarding the introduction of innovations in teaching (Fig. 10).

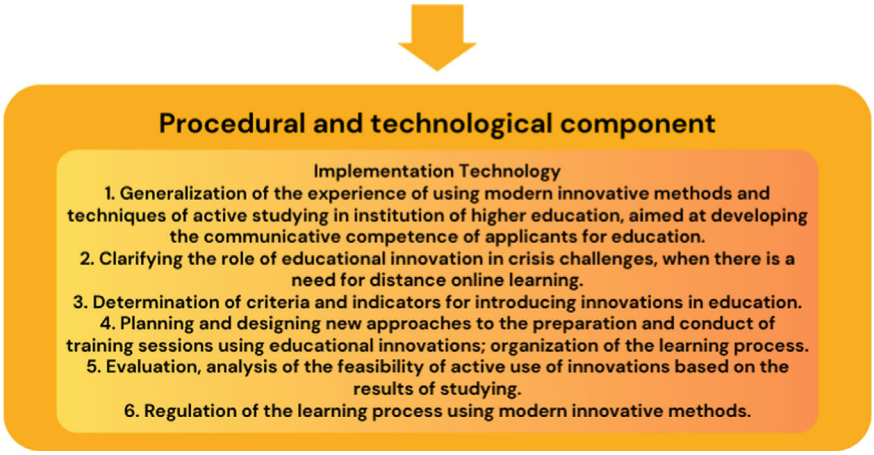

Fig. 9 Model of procedural and technological component

Fig. 10 Model of resultative and corrective component

5 Conclusions and Practical Recommendations

At the beginning of the XXI century, characterized by the development of the linguistic personality of the new generation, particularly creative, able to actively develop in the context of scientific and technological achievements and intensive innovation in all spheres of life. Therefore, there is a need to create and guarantee a safe creative environment in which it is possible to apply the latest teaching methods to form professional linguistic and communicative competence of applicants and improve the quality of education at all levels.

Ensuring the functioning of such an environment is facilitated by the capabilities of multimedia educational programs, which are expanding yearly, enriching the educational environment with bright and dynamic visibility. The use of computer technologies in the learning process opens up access to new sources of information, increases the motivation of applicants for education to receive and process professional information, increases the efficiency of independent work, gives new opportunities for creativity, acquisition, and consolidation of professional skills, the ability to implement qualitatively new forms and methods that provide communicative learning—a system dialogue with applicants using digital platforms.

The methods and technologies analyzed above show that to activate the process of forming a creative person's professional linguistic and communicative competence, it is necessary to constantly improve pedagogical skills and actively combine various technologies in practical activities to train specialists. Innovative technologies diversify and significantly enrich teaching, they are effective tools for the development of professional linguistic and communicative competence. Traditional work is complemented by intellectual creative search, in the process of which a new type of personality is formed—possessing creative thinking, active and purposeful, focused on constant self-education and development. Interactive learning is an effective way to improve the quality of the educational process, such activities contribute to the development of creative thinking, and the formation of professional linguistic and communicative competence of a creative person. Professional linguistic and communicative competence is a complex indicator of the formation of a system of professional knowledge, communicative skills, and ability, value orientations, general humanitarian culture, integral indicators of the culture of speech necessary for high-quality professional activity of a linguistic person (applicant for higher education) and a tool for the formation of a creative person (professional). Distance learning is an important subsystem that provides applicants with access to quality education. The evolution of distance learning during martial law and migration processes activates the use of new technologies, organizational forms, and innovative methods, contributing to the continuous learning of students, the organization of platforms for access to educational materials, and maintaining contacts with teachers.

Innovative technologies provide access to non-traditional sources of information, increase the level of efficiency of independent work of applicants for higher education, and open up new opportunities for creativity, search for material, and generalization of knowledge acquired in the classroom. However, it is worth combining innovative approaches and technologies with classical teaching methods, and traditional principles of educational activity. We see the prospects for further research in the development of pedagogical tools for the formation of an innovative personality in the educational environment of modern Institution of higher education.

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Added Value of Diversity for Successful Management of Smart Business Organizations

Balcová Alžbeta, Balco Peter, and Delaneuville Frédéric

Abstract Globalisation is dramatically changing the world and the way we look at it. It is a twenty-first century effect with which intercultural diversity is associated. In this bachelor's thesis, I examine culture and diversity in the workplace in a selected business company. This issue is currently being addressed by companies that operate internationally, at the same time as it is being addressed by companies that employ diverse employees. The intermingling of different cultures and ethnicities is a consequence of globalisation, whereby different employees work together in companies. I have chosen this topic as I am studying international management. At the same time, after my work experience, I have come to the conclusion that this topic is very relevant for Slovakia and also for the company where I am employed. In Slovakia, the Diversity Charter Foundation for Slovakia was established in the last decade, which offers companies the opportunity to get involved in the idea of equal opportunities for all. In recent years, opportunities have been created in Slovakia to promote diversity in the workplace, but we are still lagging behind the more advanced countries of Western Europe in certain areas. We focused on an international company where we conducted a survey, using a questionnaire and my observations from work. In developing this thesis, I have used literature, internet sources and also information provided by the company and from specific establishments that were willing to participate in the survey.

Keywords Globalisation · Intercultural diversity · Workplace culture · Equal opportunities · Organizational mix · Diversity dimensions

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1 Introduction

Diversity is all around us, cultural diversity is not inherited, but acquired through the socialisation of individuals in a community. There are people in your neighbourhood who have different traditions, beliefs, or ways of life. Learning about these cultural differences has its advantages for anyone who is not afraid of them and is willing to learn about them. Using these differences in business companies helps to break down stereotypes and prejudices in the workplace. In addition, people from other cultures contribute to the development of the company with their language skills, way of thinking, experience, and different perspectives. "What is culture? It is the total sum of all the advances of man and mankind in all spheres and in every respect, in so far as they serve the spiritual consummation of the individual, which is the progress of all advances" [1]. The historical origin of the term culture is from the ancient Middle Ages, when it originated from the Latin translation "colo" or "colere". In 106–143 BC, the Roman philosopher Cicero was the first to conceive of culture as the basis of human learning [2].

A great milestone in history was the English anthropologist Tylor, who in 1871 was the first to give the first modern scientific definition of the ethnological and anthological understanding of culture. In his book Pritive Culture he writes that culture is the whole which includes knowledge, belief, art, morals, law, customs, and all the other faculties and habits which man has acquired as a member of society [3].

The word "culture" can therefore be interpreted by a number of definitions and meanings. Kroeber and Kluckhohn as early as 1952 found 164 different definitions, for the term culture and the definition of culture is still not clearly established. Hofstede refers to culture as the collective programming of the mind that distinguishes members of one category of people about that of another. According to Mitchell, culture encompasses the shared values, attitudes, standards, knowledge, morals, laws, and behaviors of individuals and societies that influence how individuals feel, think, act, and view themselves.

Keller did a study on the characteristics of culture. In this research of his, culture displays these characteristics:

- culture is made by people, and it is the product of the collective-social activity and thinking of individual people,
- culture is a supra-individual, social phenomenon that outlives the individual,
- culture can be learned and is transmitted by symbols,
- culture is the management of behaviour through norms, rules, and behavioural codes,
- culture strives for internal consistency and integration,
- culture is a tool for adapting to the environment,
- culture is adaptive in the long run [4].

Culture can be said to influence human behaviour from its very foundations. It is a part of every personality that must learn these skills and further develop and maintain them. It is a manifestation of people themselves, which has its own elements such

as values, norms, opinions, attitudes. These give a culture a unique character that distinguishes it from other cultures. Every deviation of culture is a way in which we divide or define reality. Culture is reflected in the way people think, feel, communicate and act. It is inherited over generations from elders to younger ones. It presents the way we are able to perceive and organise ourselves and our surroundings. It can be understood as a way of living, thinking, feeling or acting that individuals have acquired in the course of their lives [3].

1.1 The Concept of Diversity

Diversity is described in the dictionary as difference or distinctiveness at the same time it represents the fact that in a society group of different people who have different opinions or ideas form a society [5].

Velíšková states that diversity with a broader meaning refers to an idea that aims to create conditions throughout society and especially in the business sphere that enable all people, regardless of their individual differences, to develop to their full potential and to show their personal potential. It is an opportunity to ensure a cultured society through an understanding of each other's diversity, and a solution for eliminating discrimination and prejudice in the world [6].

"Diversity (diversity) is any dimension by which we can distinguish groups and people from each other. It is the conscious acceptance of the fact that we are diverse as human beings in terms of age, gender, ethnicity, religion, disability, sexual orientation, education or nationality. The differences between us are both visible and invisible. Even aspects of invisible diversity, such as introversion/extroversion, cognitive diversity (different ways of thinking), differing work and life experiences, or the propensity to anxiety and psychological problems, have come to the fore in recent years in a proactive approach to diversity and inclusion in the workplace" [7].

Diversity in organisations and society breaks down stereotypes and gives opportunity to all without exception and without distinction of colour, gender, age, or sexual orientation [8].

According to Hubbard (Fig. 1), it is defined as a social mix characterized precisely by differences and similarities that are used to promote the achievement of the organization's goals. This organizational mix is divided into four interdependent and sometimes overlapping aspects.

Workforce diversity encompasses the group and identity situation of an organization's employees:

- Gender,
- race,
- ethnicity,
- religion,
- sexological abilities,
- physical abilities,

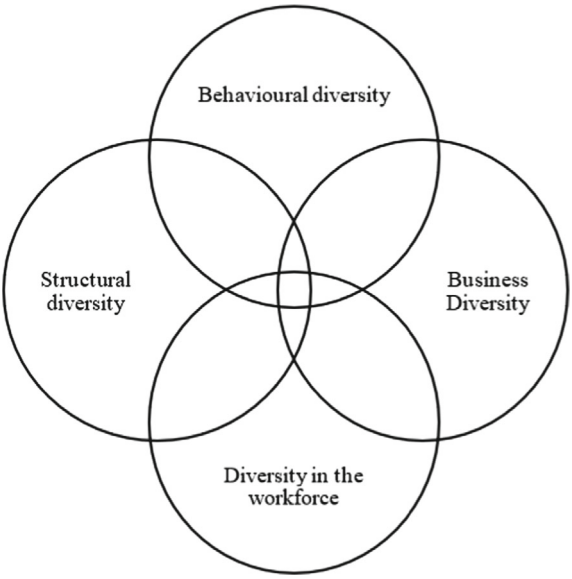


Fig. 1 Hubbard's aspects of diversity. *Source* Authors

- age,
- marital status,
- economic background,
- geographical background,
- condition,
- changes in labour market demographics.

Behavioral diversity includes work styles, thinking styles, learning styles, communication styles, desires, beliefs/values, as well as changes in attitudes and expectations of the company's employees.

Structural diversity includes interaction across functions through organizational levels in the hierarchy, across divisions, between parent and subsidiary companies, and between organizations involved in strategic alliances and differences. As organizations attempt to become more flexible (less layered and more team-based) measuring this type of diversity will require more attention.

Business diversity encompasses the expansion and segmentation of customer markets, the diversification of products and services offered, and the variety of operating environments in which organizations operate and compete. Increasing competitive pressures, globalization, rapid advances in product technology, and changing customer demographics within domestic markets as well as in foreign ones signal the need to measure an organization's response to an impact on business diversity [9].

The concept of diversity in an organizational context first emerged in the 1980s in the U.S.—here an initiative was launched to create a more positive business perspective and provide equal employment opportunities for diverse minority groups. The

initiative later evolved into a comprehensive business-oriented strategy for human resource management and development, organizational culture, and leadership. Since then, the idea has gradually gained recognition and by the mid-1990s was at the forefront in Europe in the form of so-called equal opportunities programmes. It was not until 2 October 1997 that the Treaty of Amsterdam was signed, which speaks of a common pan-European policy on diversity. The Amsterdam Treaty, together with the relevant EU Directives of 2000, 2002 and 2004, were, called to act against discrimination on the grounds of age, sex, disability, ethnic origin, religion or sexual orientation [10].

1.2 The Dimensions of Diversity

Diversity in the workplace is not only the right thing to do, but also necessary for a well-functioning company. Diversity is made up of two dimensions:

- the primary dimension of diversity
- the secondary dimension of diversity.

When the work environment allows each individual to develop, be themselves and express themselves without fear of judgement, it will help the whole team to grow and improve. The inside is called the core and is made up of six parts (Fig. 2). The outer layer is composed of parts that are tied to the primary and are called the secondary [9].

The primary dimension according to Hubbard is composed of the aspects of age, gender, ethnicity, mental and physical characteristics, race and sexual orientation. These six components of core diversity have a significant impact on human socialization at every stage of life. These dimensions represent the qualities and characteristics that form the core of each personality. All individuals have different dimensions of diversity that are shaped by the environment in which they live. In addition to the six primary dimensions, there are several secondary dimensions that play an important role in shaping our values and experiences.

The secondary dimensions include family status, socioeconomic status, communication style, educational style, religion, geographic affiliation, work environment, parental and family status, military service, education, and commuting. It also includes information about the individual's background, i.e., whether he or she is a native or a foreigner or a smoker or a non-smoker.

In general, the components of the secondary dimension are less recognizable to an individual's surroundings, but many give choice or control over one's own characteristics. People are usually less sensitive to the secondary dimensions because they have the ability to change this information about themselves or hide it from others. For individuals, the primary dimensions are important, yet we are very influenced by where we live, whether or not we are married, and what our financial status is. Primary and secondary dimensions help us to perceive our uniqueness [9].

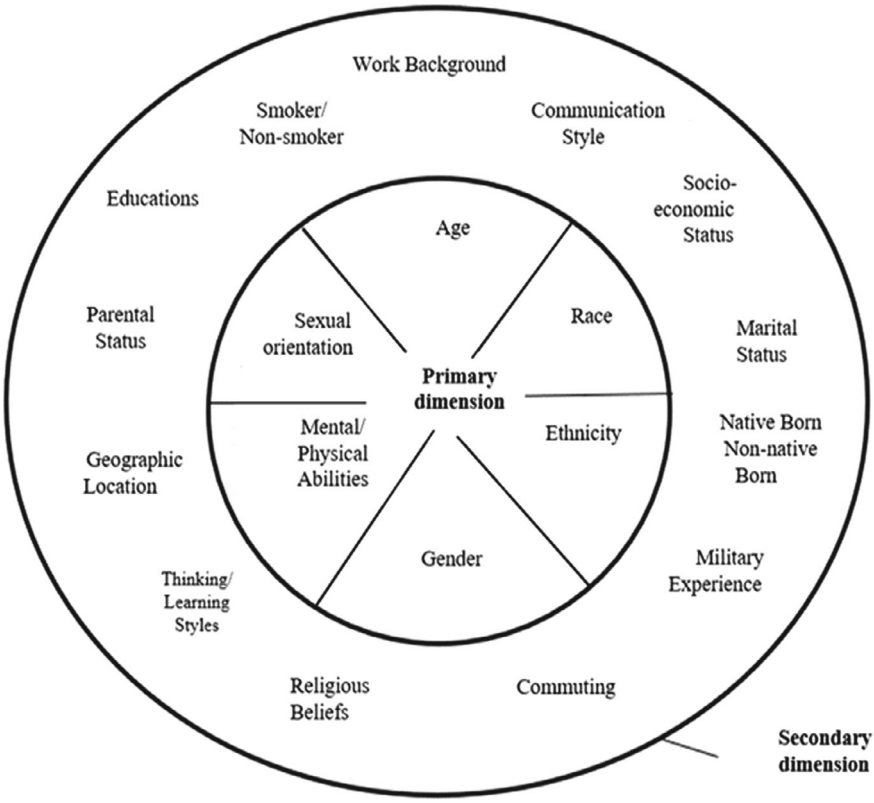


Fig. 2 Primary and secondary diversity dimensions. *Source* Authors by Hubbard [9]

1.3 Dimensions of National Cultures

Within the development of people and the course of their lives, socio-cultural regulative skills are acquired. Through social learning, people develop specific ways of behaving, feeling, thinking and thus the individual becomes a carrier of culture. In each individual, we can see the influences of the unique characteristics of the society in which he or she grew up that affect his or her development. These are, for example, the conditions of life, the country in which a person is born, his upbringing in the family, his attendance at various educational institutions, or the influence of faith. All the factors that influence a person's life from birth also influence what cultural values he or she will profess and share, and what cultural group the individual will be in [11].

Hofstede's view is that from early childhood onwards, people go through different stages throughout their lives, during which they acquire different values, have different experiences and as a result go through several levels of mental programming.

According to Hofstede, the basic levels of mental programming or levels of culture are:

- the level of national culture,
- the level of culture associated with a particular ethnicity, religion or language,
- the level of culture of a particular gender,
- the level of culture associated with the generation in which we are born,
- the level of culture associated with a social class,
- the level of organisational culture [12].

Hofstede's first cultural typology was developed based on research on cultural difference and published in 1980. The research was conducted in the 1960s and 1970s involving IBM employees. The four core and problem areas defined by Inkeles and Levinson, more than twenty years later empirically documented in research at IBM, formed the dimensions of culture. The individual dimensions were named as follows:

- large versus small power distance
- collectivism versus individualism
- masculinity versus femininity
- uncertainty avoidance versus risk aversion [12].

Hofstede's research has inspired many other researchers, such as the Hong Kong-based Canadian Bond who conducted the 1987 Chinese Values Survey [13]. Based on the research conducted and its results, a fifth dimension, short-term versus long-term orientation, was added to the basic four dimensions [12].

In the first decade, Hofstede was contacted by Minkov, who was engaged in various cross-national analyses from publicly available transnational data collected through the World Values Survey [14]. Minkov found new relationships that became the sixth cultural dimension and thus unbridled versus self-control [15].

- **Dimensions of national culture according to Geert Hofstede**

Geert Hofstede and the team of people who helped him came up with six basic questions that people need to work with in order for humanity to achieve an organised society. They are called the dimensions of culture, and each is expressed on a scale [16].

- **Power distance**

The first defined dimension is power distance, which defines the degree of power redistribution in society. Hofstede defined this dimension as the extent to which the less powerful members of institutions and organizations in a given country assume and accept that power is unequally distributed. The research on the first dimension itself also used three questions to calculate the power distance index (PDI), which shows how rank-and-file employees perceive their work environment. The power distance dimension indicates the extent to which unequal distribution of power is accepted within the company.

Cultures with low power distance are characterised by equality, in these organisations' decisions are delegated and organisational structures function well. There is interdependence between rank-and-file employees and managerial positions. Organisations with the opposite situation, i.e., high levels of power distance, tend to have an authoritarian leadership style. In these cultures, subordinates are unlikely to disagree with higher power or authority. Countries such as the USA or Germany are characterised by lower power distance. In contrast, countries from the Asian continent reach a higher degree [12].

- **Collectivism versus individualism**

This dimension describes the extent to which the interest of the individual or the interest of the group is at the forefront of society. In most cultures, the interest of the group outweighs the interest of the individual. Societies in which the interest of the individual takes precedence over the interests of the group are referred to as individualistic. Individualism is characterised by societies in which the individual and his or her needs are given higher priority. In these cultures, it is normal for only one parent to provide for the entire family. In societies characterized by collectivism, the interest of the group is more important. Collectivism describes societies in which a person is integrated from birth into strong, closed groups that protect him or her throughout life and demand unconditional loyalty. These groups may also be called extended family and are a lifelong commitment. Whereas countries like Guatemala, Ecuador, Panama are strongly collective cultures. On the other hand, USA, Australia and UK are characterized by strong individualism [12].

- **Masculinity versus femininity**

The third-dimension deals with what characteristics are prevalent in society (so-called masculine or feminine). The relatively masculine orientation of society is characterised by the pursuit of material goods, success, heroism and is strongly performance oriented. On the other hand, the feminine orientation is characterized by a greater emphasis on quality of life, emotional climate, and social and interpersonal relationships. In feminine societies, members' behaviour is based on cooperation. The countries of Slovakia, Japan, Hungary are more masculine oriented. In contrast, feminine values are strong in Scandinavian countries such as Norway and Sweden [12].

- **Uncertainty avoidance versus risk appetite**

Uncertainty avoidance can be defined as the degree to which members of a given culture feel threatened by uncertainty or unfamiliar situations. Unlike other dimensions, this one is subjective. It is a feeling that is expressed by nervous tension. Uncertainty avoidance should not be confused with risk avoidance, or how individuals respond to risk. There is no probability in uncertainty, and we cannot anticipate what may happen. A culture characterised by strong uncertainty has a low tolerance for differences and variation. Members of this culture may react poorly to more difficult situations for which they are not prepared in advance. Conversely, members of a culture with a focus on weak uncertainty tend to take more risks and be more

innovative. Thus, people are not afraid of challenges and are good at improvising. Uncertainties can be avoided as much as possible by formal regulations. Singapore and Jamaica are among the countries with very low levels of uncertainty avoidance. In contrast, Greece has the highest degree of uncertainty avoidance. But countries such as Portugal and Guatemala also tend to define strong uncertainty in society [12].

- **Short-term versus long-term orientation**

The fifth dimension was added to the first four only later and is largely derived from the teachings of Confucianism. Bond described the opposing poles as positive, which expresses an orientation toward the future, and negative, which is characterized by an orientation toward the past.

Short-term oriented cultures prioritize achievable goals in the short term. Characteristics of individuals in such societies include impatience, egoism and often the expectation of quick gains. Cultures with a long-term orientation do not seek short-term success, but rather long-term solutions that are more future-oriented. They are characterized by qualities such as caring, perseverance and fulfilling social obligations. These traits enable the achievement of long-term goals, which shows a future orientation. From the index of long-term orientation we can assess that East Asian countries in particular are oriented towards long-term results. European countries are characterized by medium values, while Canada and other English-speaking countries and Pakistan are considered to be strongly short-term oriented [12].

- **Indulgence versus restraint**

The last dimension deals with the needs of individuals. This dimension Minkov defined unconstrainedness as the tendency to make relatively free choices of basic human desires related to the enjoyment of life. Its opposite pole is constraint, which reflects the belief that gratification must be limited and regulated by strict social norms. People from high degree countries such as Venezuela and Mexico tend to be unwilling to recognize their impulses and desires when it comes to life and entertainment. They have a positive attitude towards life and are characterized by optimism. On the contrary, low to zero-level countries such as Egypt and Pakistan, i.e., high degree constraints, strongly control their lives and consider higher principles. These studies have found that the very countries that are characterized by a higher percentage of happy respondents tend to be poorer [17].

- **Comparison of the USA and Slovakia according to Hofstede's dimensions**

The chart compares Slovakia with the USA according to Hofstede's cultural dimensions. We compare the size of power distance, individualism versus collectivism, masculinity versus femininity, uncertainty avoidance versus risk aversion, long-term versus short-term orientation, and unrestrained versus controlled.

Graph shows that the Slovak Republic and its people are hierarchical and respect their superiors and can accept their decisions. The USA is characterized by its liberality, fairness and freedom for all. Hierarchy is found in society, but superiors are more benevolent and rely on their employees. Society is therefore loosely connected, people do not rely on the system but on themselves and their families.

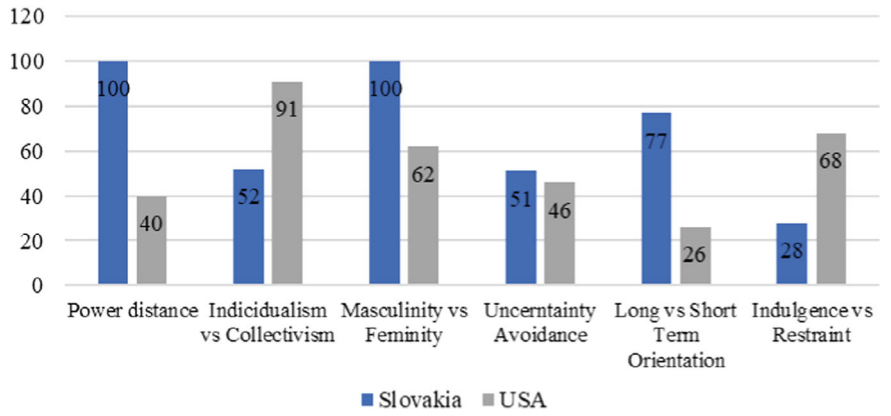


Fig. 3 The cultural dimensions by Hofstede. *Source* https://www.hofstede-insights.com/country-comparison/slovakia,the-usa/

The US with its score of 91 is one of the individualistic cultures. Slovakia's position in the middle of this dimension shows the society's unclear preference between individualism and collectivism. In the next dimension, masculinity versus femininity, Slovak society had a score of 100 and thus tends to be masculine. Slovakia is a strongly masculine society, individuals are success oriented. The inhabitants have property backgrounds such as expensive cars, houses, or designer clothes. People work hard to prove their achievements to others. In the US, this dimension is also at a higher level, thus also characterized by masculine values.

In the fourth dimension, the two countries are very similar and their resulting values are about in the middle of the graph. Thus, they do not show completely accurate characteristics of individuals, but we can say that they are not afraid to try new technologies, to be innovative and tolerant. At the same time, they feel insecure in situations that may threaten them. Slovakia's score of 77 means that it is a pragmatically oriented culture. The inhabitants are able to adapt more quickly to conditions and are persistent in achieving results. This is in contrast to the highly short-term oriented USA where individuals expect quick success.

The last dimension for Slovakia means that the inhabitants control themselves and cherish higher principles (Fig. 3). The USA also achieves contradictory values in this dimension, which shows a society where people listen to their inner impulses [18].

1.4 The Benefits of Diversity in the Workplace

Organisations that embrace the opportunity for diversity in the workplace are able to gain advantages over competitors, but also shape the perceptions of other external

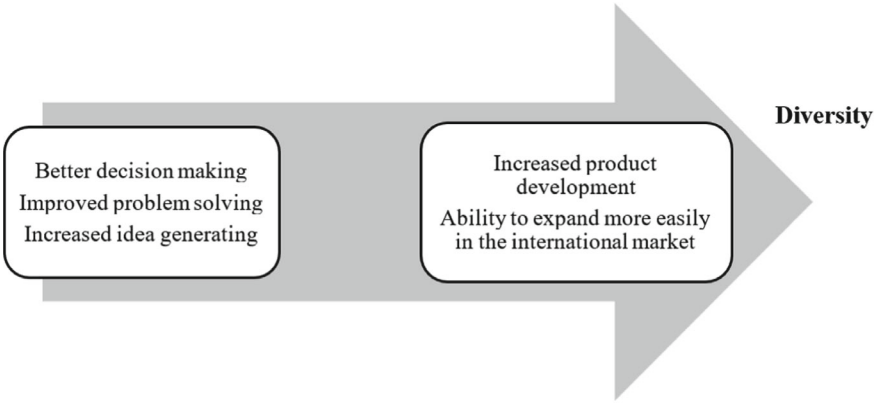


Fig. 4 Potential benefits of diversity in society. *Source* Authors

stakeholders on the topic of diversity in the organisation. Diversity brings significant potential benefits such as better decision-making, improved problem-solving, or increased idea generation (Fig. 4). These aspects lead to increased product development and the ability to expand more easily in an international market with more products [19].

An organisation's success or competitiveness depends on its ability to embrace diversity and realise its benefits. If diversity is properly implemented in the workplace, it results in multiple benefits for employers and employees alike. Benefits include:

- The perspective,
- The ability to attract the best talent to support the business,
- Building a globally competitive work team,
- The ability to avoid conflict, increase individual performance and retention,
- Job opportunity for the same position,
- Tolerance,
- More effective implementation,
- More effective problem solving [19].

- **Perspective/point of view**

Organisations using a diverse workforce can get a range of views on any project. Employees bring individual talents and experience that can help a company adapt to volatile markets and customer demands. When a company encourages other groups to express their honest opinions, it will help the company prosper when it comes to marketing and selling the product or business.

- **Ability to attract the best talent to support the business**

If an organization has built a reputation for diversity in the workplace, it will help the organization attract the best available talent and capability in the marketplace, both domestic and international. As a result of the different languages and diverse backgrounds of its employees, the company will find it easier to market its products. In addition, these companies will be able to develop collaborations with strategic partners located in more distant markets.

- **Building a globally competitive working team**

With many diverse cultures in the world and increasing globalisation, it is crucial that employers and employees embrace diversity in the workplace. In order for a company's products and services to be designed to meet different customer needs, organizations should hire people from diverse backgrounds as these workers have diverse insights and knowledge.

- **Ability to avoid conflicts, increase individual performance and employee retention**

Employees are always striving for a sense of belonging in the organization they work for. At the same time, you need to listen to your employees as their productivity can be increased by doing so. Employees will always contribute more to their workplace when they feel that their ideas and beliefs are supported. Therefore, a work atmosphere that is not healthy can result in an adverse effect on workers which can lead to exhaustion. Employees who do not feel that they are being treated fairly, with respect and deference will begin to look for new opportunities, which may result in losses for the company they left. One of the main benefits of diversity in the workplace is that it provides a healthy environment that recognizes and compensates for team performance and encourages employees to express themselves with an open mind, leading to high levels of productivity and low employee turnover.

- **Job opportunity for the same position**

When a workplace is diverse, it shows that it provides equal opportunities regardless of background, race or gender and does not discriminate against certain individuals. A more diverse workplace is perceived from an outside perspective as more open to accepting qualified applicants. It is also important to mention that companies that consider workforce diversity important are perceived as socially responsible to their surroundings.

- **Tolerance**

Dealing with people from different cultures improves the level of personal tolerance of each individual employee. Diversity enriches the work environment because everyone within the organization will put in extra effort to overcome individual differences resulting from a diverse workforce.

- **More efficient implementation**

Companies that promote diversity in the workplace encourage all of their employees to perform at their best. This leads to higher productivity, profits and return on investment.

- **More effective problem solving**

A diverse workforce of different age groups and genders, with different educational backgrounds and experience, will be able to bring multiple solutions and ideas when confronted with a business problem located on another continent. Today, a diverse workforce is the standard for an organisation facing the fluctuating trends and demands of globalisation [19].

2 About Company

In our research, we studied a large international company that operates around the world. The main pillars of the business that remain unchanged are the company's employees, license owners or operators, and suppliers. However, the main goal is to always provide the same high quality of ordered product, service, i.e. fast, accurate, friendly service in a clean, value-added environment to every customer in every circumstance.

This global company fully supports diversity and equal opportunities for all. It has dealt directly with the topic of diversity in the workplace in recent years. In Slovakia and the Czech Republic, this is regulated directly by law, but diversity is a hot topic across the board. The company's vision of diversity is the synergy of employees' unique talents, strengths and contributions to be able to provide the best service to the fast food restaurant. They continually strive to maintain an environment where everyone feels valued, accepted and appreciated as an integral part of the team. The organization encourages its employees to understand and acknowledge the possible differences between them and to appreciate the value that all the different groups and individuals bring to the system. It is important that these differences are used to build and improve relationships in the workplace or with colleagues or customers [20].

In 2019, the brand, which also operates in Slovakia, has become an ambassador of the Charter of Diversity, which operates in the Slovak Republic, where, in addition to its rights, it is also committed to respecting certain rules:

- respect diversity,
- do not compromise,
- preserve and strengthen diversity,
- value diversity,
- integrate diversity management,
- to set an example [21].

Based on these 6 points, it ensures an inclusive approach in the workplace, regardless of possible diversity. It is important to provide an environment against possible prejudice. At the same time, it seeks to build mutual trust and respect among employees, but at the same time protect employees from any form of discrimination. The restaurant manager has the task of creating an environment in his restaurant where his employees feel valued and respected, where they behave politely among themselves and show respect for each other. An 'open door for all' policy is practised by the company in all its establishments to ensure that employees do not feel uncomfortable in the company of their supervisors. "My job is to take care of the employee so that they feel comfortable with us from the moment they first come to us. That's the same as with a family" [22].

In addition to internal influences, this company wants to increase diversity awareness in its community. This, of course, also requires a certain amount of employee education on the subject. In addition to welcoming diversity in its employees, licensees, customers and business partners, the company strives to make everyone feel at home [23].

In addition to promoting diversity through the Diversity Charter, the company is actively involved in other projects such as Women in Leadership. It has long been known that Slovakia is at the tail end of gender equality and that is why we suffer from a lack of women in leadership. That is why the company has announced the launch of its new global strategy, which aims to improve the representation of women at all levels of society by 2023, to achieve gender equality in career advancement and to strengthen the influence of women on business itself. Global Top Management has pledged to increase the number of women in leadership roles to 45% by the end of 2025, in order for the company to achieve gender parity by the end of 2030. Like the rest of the world, the company strives to ensure equal employment opportunities for both women and men [24]. Employee Diversity scores 66/100 across various culture categories. This diversity score provides insights into how diverse employees feel about their work experience and rate their work experience across various dimensions of culture. Management Company is committed to creating a workplace where everyone is equally supported and empowered to realize their full potential. Like the golden arches themselves, the goal is to make everyone feel comfortable, safe and welcome [25].

2.1 Results

The first ten questions helped us to characterize the respondent who completed the questionnaire. The remaining questions provided us with many responses. We used these in our proposed recommendations to the company. Observing the employees directly in the plant showed us to what extent these answers might be relevant. The questions in the questionnaires were directed at employees to find out how they

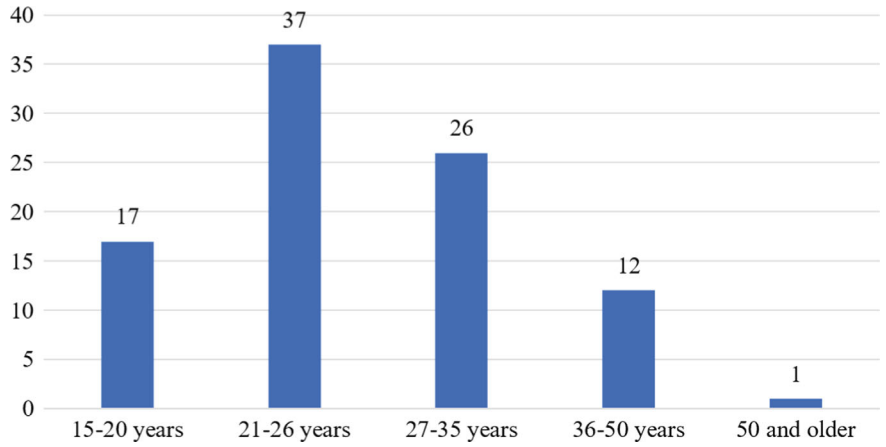


Fig. 5 Gender of the respondent. *Source* Authors

perceive the issue of intercultural diversity in their workplace and in their environment. The final number of questionnaires completed was 93. Employees answered 36 questions, where the first 9 questions were directly related to them (Fig. 5).

A total of 93 respondents took part in the questionnaire survey (Figs. 6 and 7), of which the percentage of men was 47.3% and women 52.7% [26]. We divided the age of the respondents into 5 main groups, which we deliberately chose. As we expected, the most common age of the respondent was 21–26 years. This was followed by a group of 27–35-year-old employees and teenagers. Only 14% of the respondents were over 36 years of age at the time the questionnaire was completed.

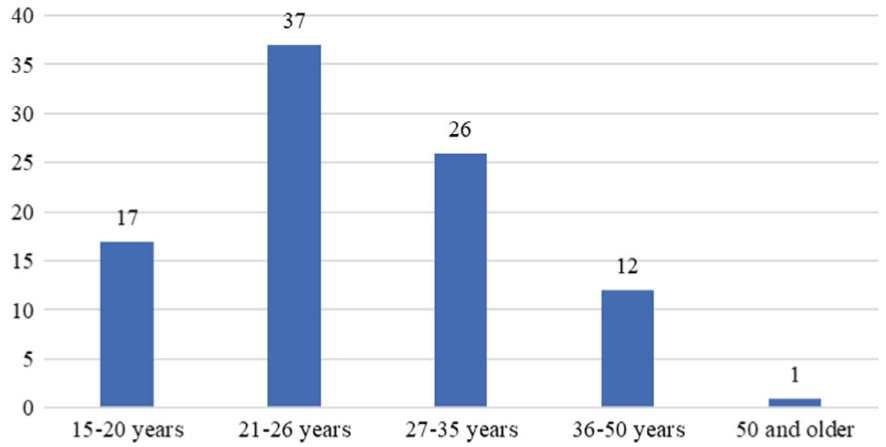


Fig. 6 Age of respondent. *Source* Authors

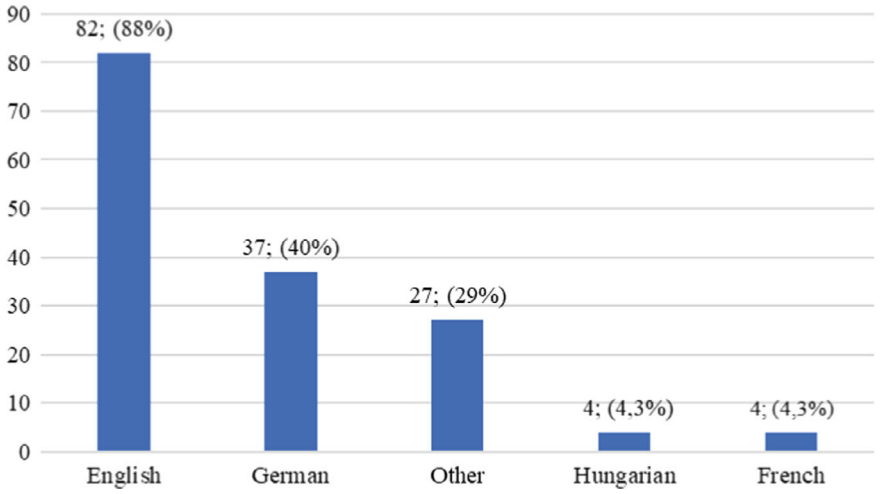


Fig. 7 Respondent's language skills. *Source* Authors

Retirees are also frequent employees of the establishments, either needing to improve their financial situation or wanting to fill their leisure time. Interestingly, an elderly lady in a Slovakian establishment celebrated her 80th birthday [26].

In Fig. 7, we were interested in the language skills of the staff. As many as 88% of employees speak English, the second most common language was German, which is spoken by almost 40% of employees. French and Hungarian are spoken by only 8% of employees. Among other languages, respondents wrote that they know Russian, Spanish, Czech, Polish, Italian or Romani. Two respondents answered that they did not know any foreign language [26].

We next ascertained whether the respondents were new to the corporation or had been employed with the corporation for a longer period of time. Through a contingency table by combining this question and question number two, we found out the required information. The higher the age, the longer the employees have been working for the brand. It shows that the employees are steady and loyal to the brand. At the same time, they are satisfied with the conditions in it (Fig. 8). According to this data, it can be assessed that for many it is the very first job since high school or college [26].

Figure 9 shows the company's operations. And the chart shows us the refinement of the individual job positions. This breakdown is common wherever in the world the company operates. Crew is a rank-and-file operational employee who is part of a team in operations. A crew trainer is also part of the team in the restaurant and is responsible for conducting regular crew training. In total, up to 37.7% of the questionnaires were from these employees. Most and thus almost 2 thirds of the questionnaires were from employees working in managerial positions (Fig. 10) such as operations manager, assistant or supervisor position and the office department [26].

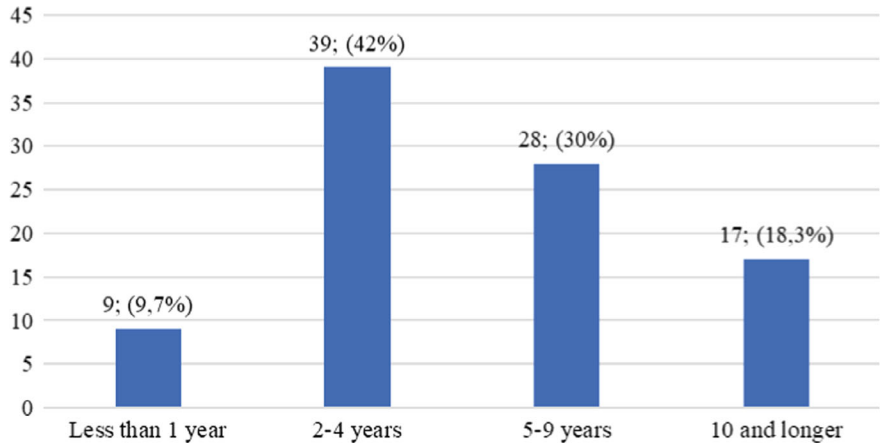
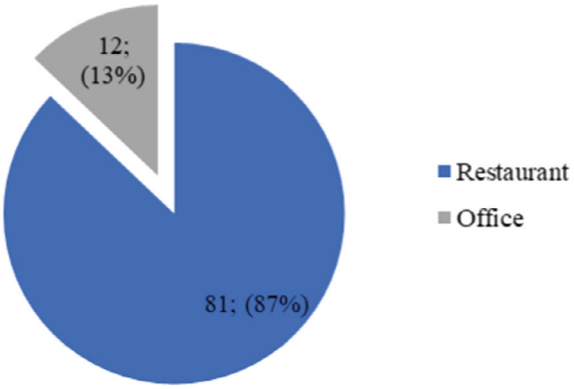


Fig. 8 Duration of employment relationship. *Source* Authors

Fig. 9 Respondents' sector of activity in the company. *Source* Authors



The first diversity-related question asked whether employees were familiar with the concept of intercultural diversity, or whether they had encountered it outside of work. Almost one-third of employees are familiar with the concept from work, either from workshops or through internal communication. In the following open-ended question, employees could answer what diversity in the company means to them (Fig. 11). Many respondents defined it as diversity, difference, equality or understanding. Having a multicultural team in the operation can be a positive thing for everyone [26].

From Fig. 12, we found out the percentage distribution of men and women in leadership positions. According to the questionnaires, the ratio is almost the same, which shows that McDonald's does not discriminate and gives women the same opportunity for a higher position in the company as men [26].

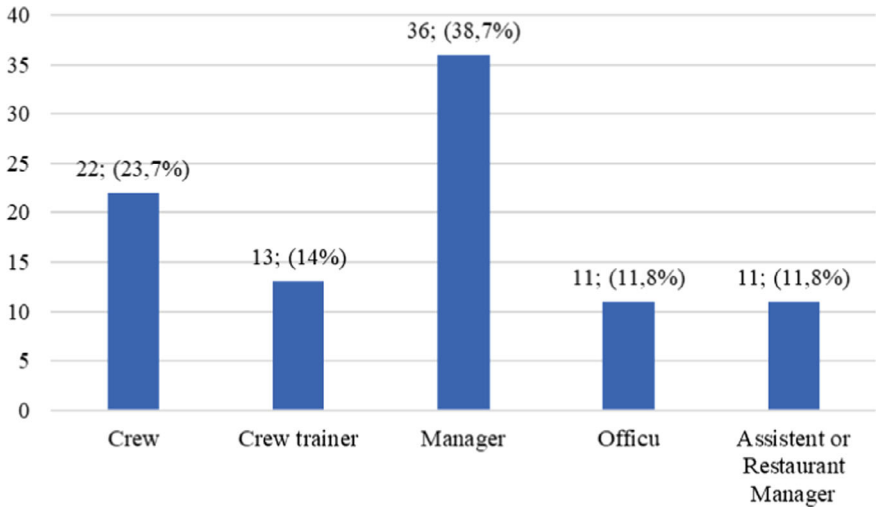


Fig. 10 Job position of respondent. *Source* Authors

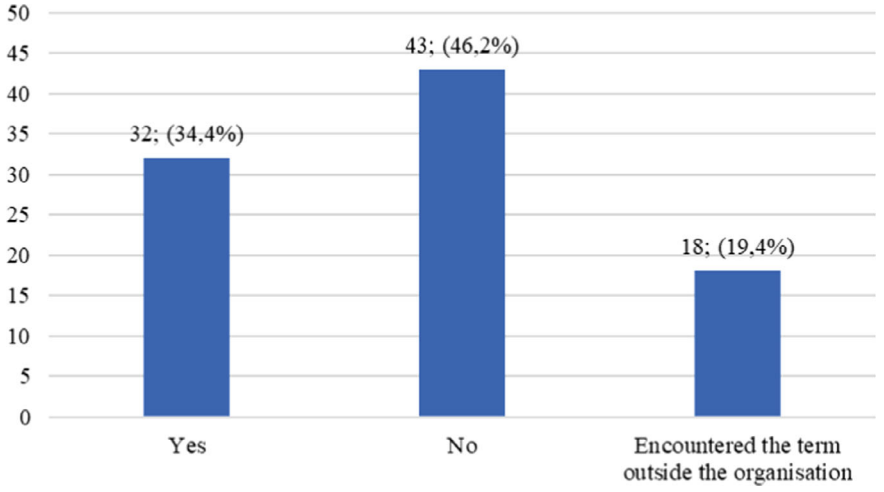


Fig. 11 Introducing the concept of intercultural diversity. *Source* Authors

Just as the company presents itself in the external environment, it upholds its commitments within its organisational structure (Fig. 13). Up to 37% of respondents have colleagues of retirement age [26].

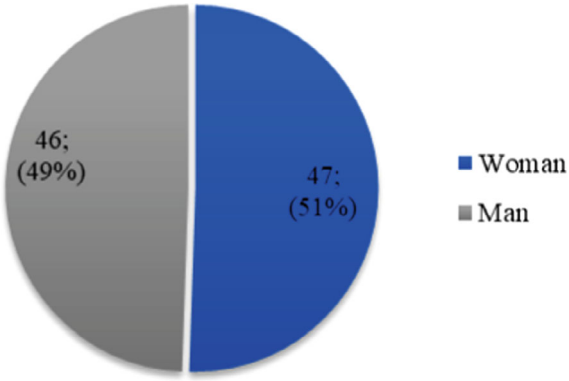


Fig. 12 Gender of the. *Source* Authors

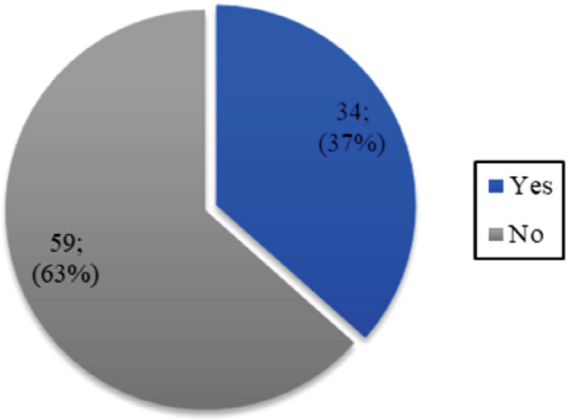


Fig. 13 Are your colleagues of retirement age? *Source* Authors

In Slovakia, society does not discriminate and tries to employ people with health problems or disabilities if their disability allows them to work (Fig. 14). It also actively cooperates with vocational secondary schools for mentally handicapped children, which employ them for work experience. It also supports sheltered workshops with its purchases, from where it provides seasonal gifts for its employees and customers [26].

The largest group of employees are parents who earn extra income alongside their maternity leave or have young children and need flexible working hours to support them. These employees are most often seen working in the early hours of the morning or in the morning.

In the graph we can see that there are also employees in the company who have prejudices or are reluctant to work together in a multicultural team (Fig. 15). This is often due to a language barrier, a bad experience from the past or fear of something unfamiliar. The reassuring thing is that the figure of 4% is really low.

In the next question, employees were asked to say what the reason for their answer to this question is. Many people associate a multicultural team with foreign languages.

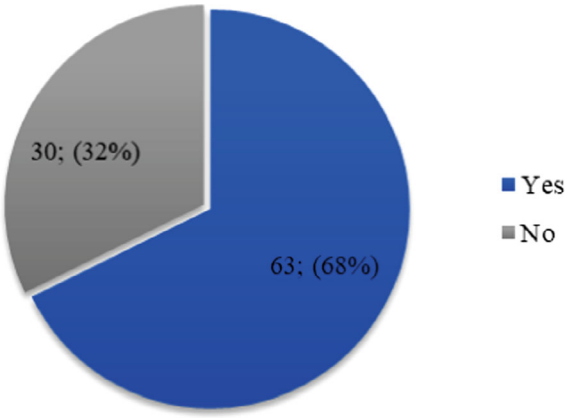


Fig. 14 Are your colleague's people with health problems or disabilities? *Source* Authors

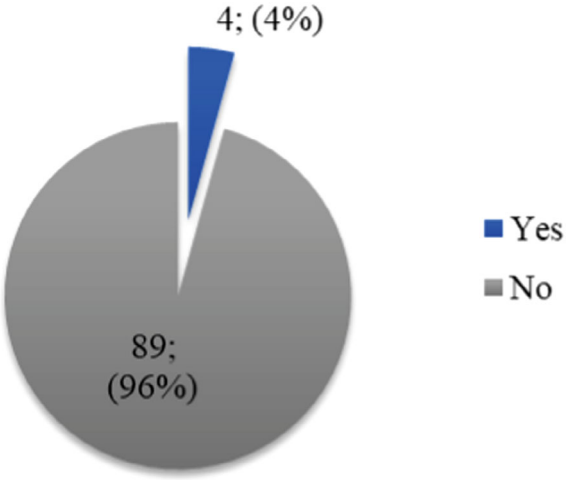


Fig. 15 Challenging to work in a multicultural team. *Source* Authors

A lot of respondents see the positive side of being able to communicate in languages other than their native language. For others it is the charm of the company, and they feel comfortable in the company of diverse people. Most respondents do not look at multicultural differences as long as it does not affect their work. Those who said they have a problem working in a culturally diverse team, when asked "why?" did not answer [26].

Although the company tries not to discriminate and to prevent discrimination and problems in its operations, it does not succeed in every circumstance (Fig. 16). More than half of the respondents indicated their answer as a definite no. The others either directly encountered discrimination or tried to ignore it.

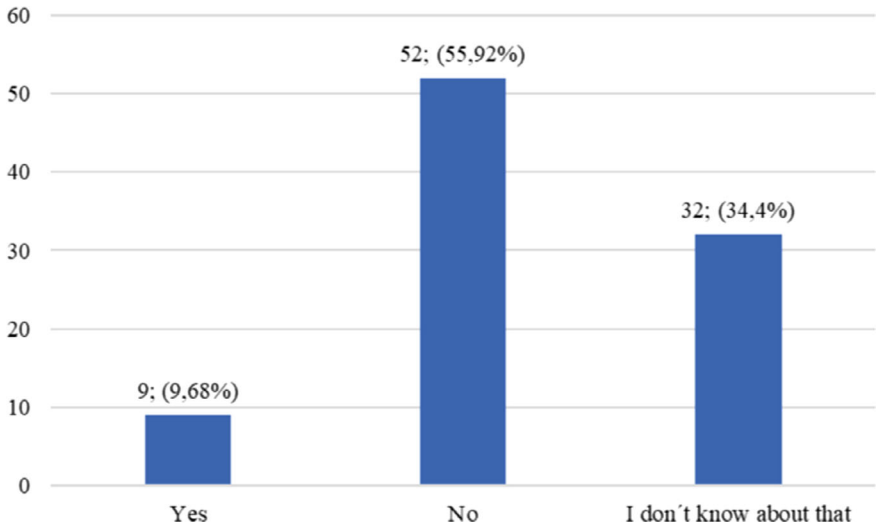


Fig. 16 Problem situation related to culture, origin, age or religion. *Source* Authors

The next open-ended question was addressed to those who answered yes to the previous question presented in Fig. 19. We asked the respondents how the problem had been solved. One of the topics discussed was the issue of religion not allowing certain raw materials to be touched on the premises. Since the employee was a foreigner and did not speak Slovak, assigning him a work position was problematic. After some time, the establishment came to an agreement that he would always wear two gloves on his hands so that he would not touch the food directly with his body. Other very sensitive topics were related to race as well as domestic violence in the community. The topic of domestic violence addressed at our establishment, had to be secured through the local police. Although the organization had to deal with a variety of issues, many of them ended in compromise [26].

The following was aimed at the subjective opinion of employees, to what extent they find it more interesting to work in a multicultural team (Fig. 17). It is positive in terms of opinion about diversity that only 3.23% of employees answered no. 17.2% of respondents were undecided and the remaining number of respondents answered either a definite yes or yes [26].

In Fig. 18, we see how employees rated the importance of the extent to which ancestry affects their supervisors' managerial abilities (Fig. 18). At this point, the majority were either ambiguous or said that ancestry does not impact his or her managerial abilities (Fig. 19). At the same time, 17.2% of employees think that people's origins have some relevance to their skills [26].

As a result, from Fig. 19 we can see how the organisation's policy is used in practice (Fig. 20). Although only 3.3% of all respondents had a bad experience with their supervisors, this is a figure that could be further reduced by listening more to employees and using the values presented by the organization [26].

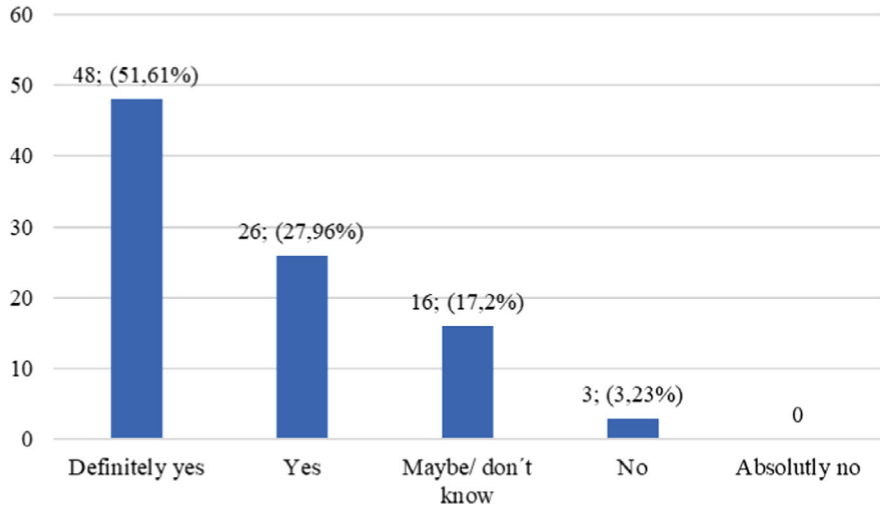


Fig. 17 Evaluating creativity in a workplace made up of a multicultural team. *Source* Authors

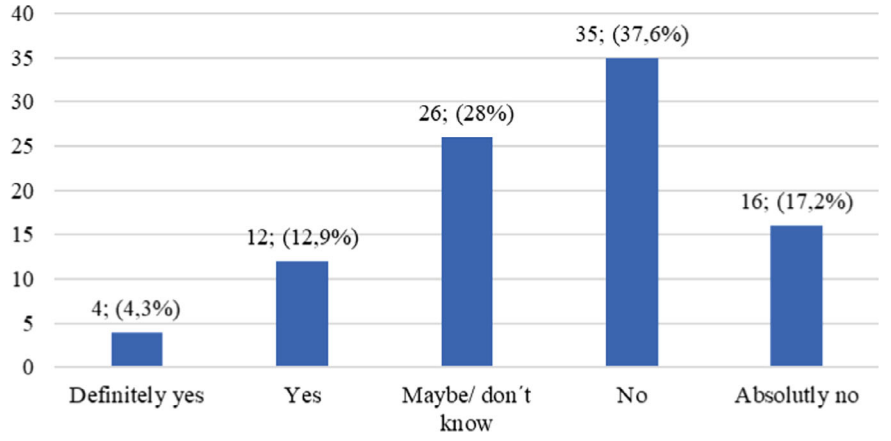


Fig. 18 Assessing the impact of origin on a supervisor's managerial abilities. *Source* Authors

The chart follows the previous one and whether the respondents were treated inappropriately by their supervisor (Fig. 21). These values already show a higher level of unprofessionalism in management towards the rank and file [26].

We could already see from the previous answers that employees are not treated equally everywhere. Establishments present themselves as creating a family environment for their employees, but this is not the same for everyone. It is possible that people in managerial positions have their favourites, which would not be a problem as long as they do not favour them over other workers at work. Also, in terms of nationalities, management's approach is not the same everywhere [26].

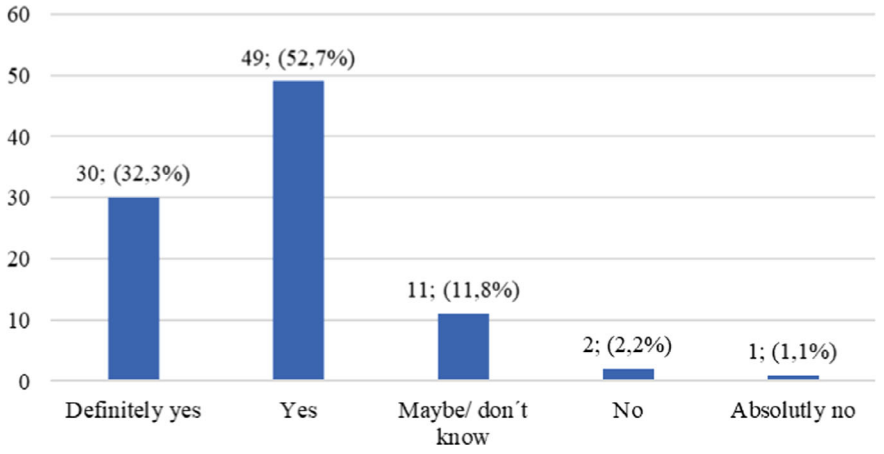
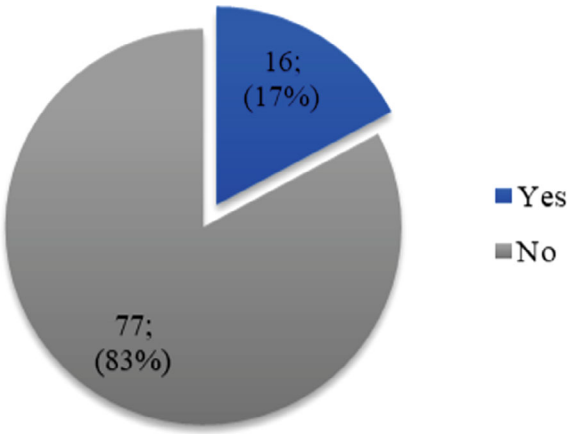


Fig. 19 Respondents' satisfaction with their supervisors' behaviour towards them in front of customers and. *Source* Authors

Fig. 20 Humiliation of the respondent in front of customers or other. *Source* Authors



The question used in the questionnaire for the graph was directed to the subjective opinion of the respondents (Fig. 22), which makes it possible to give a recommendation to the company.

These tips can only be beneficial for that organization and also its employees. 3.23% of the respondents said that the company has no room for improvement anymore. 9.68% of the employees could not indicate any of the areas listed and 1.08% of the respondent wrote that the company has the potential to develop further in all directions [26].

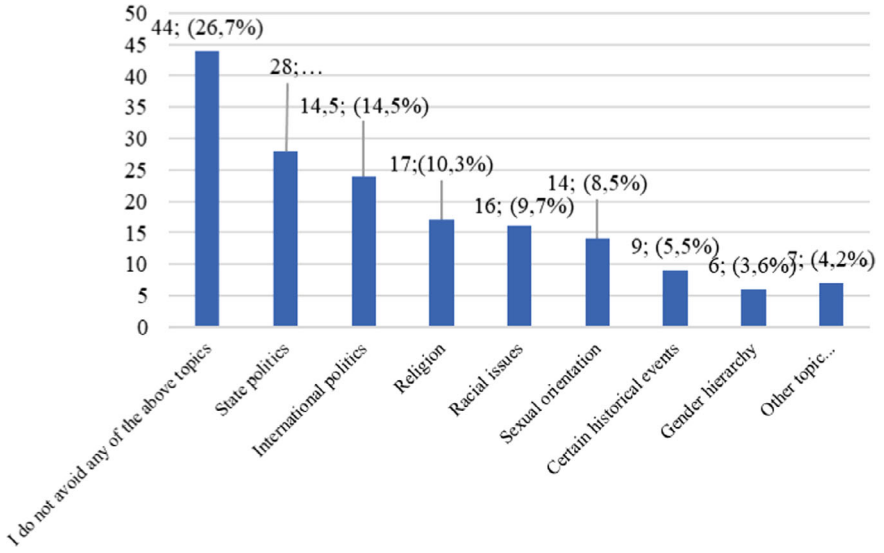


Fig. 21 Topics that employees avoid in workplace conversation. *Source* Authors

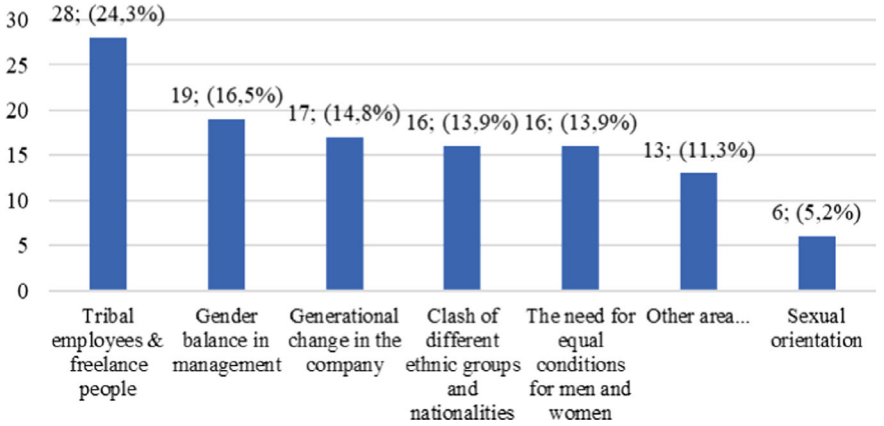


Fig. 22 An area of diversity in which the company has the opportunity to improve. *Source* Authors

3 Conclusion

In this section, we present our own suggestions aimed at improving company and employee attitudes towards the topic of cultural diversity in the workplace. Diversity is both necessary for a healthy functioning company and good for its business. Organizations that invest in and promote diversity have many advantages over companies that do not promote diversity. Attracting and retaining diverse talent is the biggest

challenge for many companies today. Although the companies surveyed declare their commitment to diversity in the workplace, there is room for improvement and development. 93 employees participated in the survey, which consisted of 34 questions. Already on the first chart we noticed that masculinity and femininity are almost balanced in this company. According to the online literature that I have included in the resources, up to 54% of the total workforce of the organization is female. Our questionnaire was completed by 52.7% women and here we can see that in the sample studied from Slovakia the ratio is almost the same as in the world. When respondents were asked about their supervisor, more than a close half 50.5% responded that their direct or indirect supervisor is a woman. According to Hofstede's dimensions, although Slovakia is a strongly masculine country, society does try to adhere to the norms of diversity in this area of diversity. Nevertheless, 16.5% of employees also said that the gender balance in management is not balanced, which is also shown by global statistics. The area of diversity that respondents identified as the weakest and that the company should pay attention to is the point of tribal employees and external associates or contract workers. The company's policy is to have as many workers employed on a student temporary work agreement as possible. Up to 70% of such contracts are made up of Slovak workers. In management, up to 40% of these temporary workers remain on permanent contracts after graduation. For junior positions in Slovakia, this figure is around 20% in relative terms. Employees see long-term security in an employer, where if you are willing to work and adhere to standards, you can work for decades in a line position in an operation. Such people become regulars in the restaurant if they are not interested in career growth.

The company has also long been committed to racial equality in the workplace. Although there are few such employees, employees of other races also work in management positions in certain operations. However, it is still not equal. The fault may not even lie directly with the behaviour of employees in the establishments, but rather with the little advertising the company shows the public. The company prides itself on advertising, and the PR department is really rich in various communications with the public. This company is one of those that have a high social responsibility towards the public, but even though on their official or internal website, they have various articles about diversity in the workplace, on social media they fall short with this. Every year in May in Slovakia, this company dedicates this month to diversity, as the month of May is diversity month. All actions are directed only to their employees and in some cases even here the communication is not the best. Not in all operation managers are willing to communicate internal information from the office to their employees and it may happen that these employees are deprived.

One of the main recommendations is that the company should place a higher priority on educating managers about diversity and its benefits in the working relationship. It is unprofessional to assume that all managers are aware of this issue and understand what it means for the company. There is a need to empower employees in leadership positions with the skills to be able and willing to lead a diverse team. One possible form of training could be team building focused on cultural diversity.

When advertising job positions or mass recruitments, it is necessary to be open to potential new hires, or for job descriptions to have a broader reach to people who are interested in employment.

Although communication in operations is highly effective, it would be useful and perhaps interesting to introduce regular visits from business consultants or other senior management to come and work a few hours a month in the operations for which they are responsible. Such visits are made, well, just to check on the operation, staff in lower positions would perhaps welcome less distance between them and management.

Certainly, the last point is very interesting, which is the exchange of employees within the Slovak operations. This exchange is regularly applied, especially when help is needed in another operation. An international exchange of an employee from another country could be an experience for the whole operation. Slovak restaurants are linked together with the Czech one and therefore we do not see a big problem, except for the financial costs, that this form of activity could not be held once a year in honour of diversity in the company. Some operations are even closer in location to countries such as Austria and Hungary. In the case of cooperation with these two countries, this activity would perhaps be more complicated, but still not impossible.

Thus, the investigated company still has the opportunity to develop in different areas of diversity in the workplace, where it will support its norms and standards for its employees.

This research focused on the topic of diversity, which we decided to pursue because we believe in its potential in the future. It is a twenty-first century topic that is being addressed by various research and foundations trying to raise awareness of this issue in society. We find diversity all around us every day, whether it is in our working or private lives. It was necessary at the beginning of this work to define and explain the basic concepts, which are the words culture and diversity. We have listed a number of opinions on this topic from both foreign and Slovak authors. We have dealt with the topic of the dimension of diversity and the dimension of national cultures. According to Hofstede's dimension theory, we compared information about two countries, namely Slovakia and the USA. It was because of which society we decided to analyse. We chose an American company that has been operating for more than 25 years also in Slovakia. Next, we described the advantages of companies that apply diversity in the workplace.

In the following chapter we characterize the diversity in the company. Since the author of this thesis, worked for the analysed company, it was easier to get to the required information, which is mainly presented in the internal materials of the company. With the help of observation, it was also possible to truthfully characterize the topicality of the topic of diversity.

The research part only reinforced to us that although the company has made efforts to create a diverse environment for its workforce, the issue of diversity is not easy to apply. The individuals that make up a company are unique and how they accept change in the system can help or hinder the organization.

Diversity is a change that came with globalization and there is no stopping this process in the modern world we live in. It is a challenge that can be an opportunity for many companies, and it is up to them and their leadership to embrace the new realities. However, the sooner companies start to react to the emerging changes, the sooner they will get a quality and modern environment for their employees.

As the author is directly from the company's background and some of the responses from the questionnaire pointed to opportunities for the company to work on, it would be useful to evaluate the results and work on this in the future. The key is to adhere to the standards and norms that the company set when it was founded and to adapt them to the changing society over the years. If certain requirements for employees were adhered to, the results of the questionnaire would be even more positive for the company. Good communication is the basis of the work, but even this has failed in some cases. If such an important link in the system fails, it can have bad effects on the whole organization. An important recommendation for the company is to organize team building events, focused on culture, which could also take place in a foreign environment. Some development of this company on the topic of diversity was also limited by the pandemic COVID-19 situation, as employees worked in separate teams for months to limit the possibility of contagion and the creation of an outbreak. Employees became accustomed to working with the same people every day and there were various small misunderstandings when the plants reopened that would not have existed if not for this situation. The question is how the company will behave when the measures that restrict its decisions come to an end. It would be advisable for there to be more cooperation between the top management and the rank and file. Events should again be organised to make a strong team out of a diverse group of people. Perhaps it is only a matter of time before society starts to express itself more positively through social channels towards the Slovak population in the area of diversity. Alternatively, it will make decisions that will result in an improved organisational and external environment in the company. Diversity is both our present and our future. Thanks to the society we grow up in, we are influenced by its culture and become unique personalities that create diversity [26].

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Unveiling Disparities and Resilience in Ukrainian Regional Labor Markets: Multidimensional Ranking Approach

Larysa Zomchak and Sophiia Hakava

Abstract This study investigates the resilience and disparities characterizing Ukrainian regional labor markets between 2019 and 2021. Employing a multidimensional approach, it combines taxonomic analysis and integral assessment to explore how economic, demographic, social, and infrastructural factors interact and influence regional labor market outcomes. The findings highlight significant regional disparities. Kharkiv, Lviv, and Dnipropetrovsk emerge as leaders, exhibiting resilience through economic diversification, strong infrastructure, and skilled workforces. Conversely, Donetsk, Volyn, and Ternopil demonstrate the lowest performance due to factors like military conflict, overreliance on agriculture, and weak infrastructure. The study underscores the importance of economic diversification, infrastructure development, and a skilled workforce for fostering robust and adaptable regional labor markets. It highlights the capacity for adaptation and resilience, exemplified by Lviv and Dnipropetrovsk's advancements. Conversely, persistent structural issues and limited investment hinder progress in regions like Donetsk, Volyn, and Ternopil, limiting their ability to adapt and improve. The effectiveness of the employed methods is confirmed. Taxonomic analysis facilitates the identification of regional trends, while integral assessment provides insights into the interconnectedness of factors influencing labor market resilience. In conclusion, this research offers valuable insights into the resilience and disparities within Ukrainian regional labor markets. The employed methods prove to be effective tools for analyzing labor markets and pinpointing crucial factors for regional economic policy development, fostering resilience and promoting a more balanced regional landscape.

Keywords Region · Labour · Labour market · Multidimensional ranking · Resilience · Disparities · Economic development · Policy development

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1 Introduction

Regional labor markets play a critical role in a nation's economic well-being. They act as vibrant ecosystems, attracting and retaining skilled workforces, fostering innovation, and driving job creation. However, these ecosystems can exhibit significant disparities in their performance. Uneven development across regions can exacerbate existing inequalities, hinder national economic progress, and limit opportunities for individuals seeking employment.

Ukraine, a nation with a diverse geographic landscape and a complex economic history, provides a compelling case study for examining regional disparities in labor markets. The country boasts a rich agricultural sector, established industrial centers, and a growing IT industry. However, its economic development has been hampered by political instability, the ongoing military conflict in the eastern region, and the challenges of transitioning from a centrally planned economy. These factors have undoubtedly impacted the development and resilience of its regional labor markets.

This study delves into the dynamics of resilience and disparities within Ukrainian regional labor markets from 2019 to 2021. This period is particularly interesting as it captures the pre-pandemic economic landscape, the initial shock of the pandemic, and the subsequent recovery phase. By employing a multifaceted approach, it combines taxonomic analysis and integral assessment to explore the interplay of economic, demographic, social, and infrastructural factors shaping regional labor market outcomes. Taxonomic analysis will classify regions based on various characteristics, allowing us to identify trends in economic structure, investment levels, and external factor influence. Integral assessment, on the other hand, will delve deeper, examining the combined effects of these factors on regional labor market resilience.

The primary objectives of this research are:

To identify and analyze regional disparities in Ukrainian labor markets between 2019 and 2021, with a particular focus on how these disparities have evolved over the study period.

To investigate the factors influencing regional labor market resilience in the face of economic, social, and political challenges, such as the ongoing military conflict.

To assess the effectiveness of taxonomic analysis and integral assessment in analyzing regional labor market dynamics and their capacity to inform policy development.

By achieving these objectives, this study aims to contribute valuable insights for policymakers and scholars interested in fostering regional economic development, promoting a more balanced and resilient national labor market in Ukraine, and ultimately, contributing to the nation's overall economic well-being.

2 Materials and Methods

2.1 Literature Review

Regional labour markets are a distinct field of study within labour economics, recognizing that labour market dynamics differ significantly across geographic areas. Authors of [1] examine how trade and technological advancements impact local labour markets. Reference [2] explore the role of knowledge transfer and industrial clusters in shaping regional labour market dynamics. Faggian et al. [3] investigate the link between human capital and regional development, while Simões et al. [4] analyze its role in labour market resilience for Portugal. Reveiu et al. [5] examine how the digital divide across regions impacts labour market resilience. Several studies focus on regional labour market resilience in the face of economic shocks and crises. Diodato and Weterings [6] explore the role of firm-worker interactions, while Giannakis and Mamuneas [7] investigate labour productivity as a factor. Salvati et al. [8] address the potential link between wealth and regional resilience. Faggian et al. [9] explore the concept through the lens of Italian local labour systems, and Håkansson and Bejakovic [10] examine labour market resilience, bottlenecks, and spatial mobility in Croatia. The impact of industrial robots on employment and wages within a local labour market context is analyzed in [11]. In [12], authors examine the impact of labour market reforms and economic performance on matching short-term and long-term unemployed workers. Reference [13] provide an introduction to the relationship between higher education and the labour market. Azar et al. [14] explore the effects of minimum wage on employment and labour market concentration. Reference [15] explores the situation of youth in regional labour markets. Reference [16] offer a comparative analysis of labour markets in Southeast Europe, while [17] examine the regional aspects of the labour market in Moldova. Pryimak et al. [18] analyze the development of regional labour markets in Ukraine using fuzzy analysis. Reference [19] investigate factors affecting efficiency in labour market matching at different territorial levels in Poland.

Regional labour markets are complex systems susceptible to economic shocks and require resilience to adapt and recover. Mathematical models offer a powerful tool to analyze these dynamics. Spatial econometrics approach is employed in [20, 21] to examine the impact of regional inequality and tourism clusters, respectively. Reference [22] utilize it to analyze the embeddedness of European regions in research and development networks. Autoregressive Distributed Lag (ARDL) models are used in [23] to explore the relationship between economic growth, gender inequality, and female labour force participation. The authors of the article [24] used cluster analysis on the regional level and the authors of [25] used a taxonomic analysis, in [26] nonlinear modeling is used and machine learning techniques in [27]. Al Mamun et al. [28] apply it to investigate the impact of remittances on labour productivity in Bangladesh, while [29] examines the contribution of human capital investment to economic growth in Eastern and Southern Africa. References [30, 31] utilize models to understand regional labour market dynamics in space and time within a spatial

context. Kivi and Paas [32] model the spatial interactions of employment in European labour markets.

Some research that focuses on various technical aspects relevant to data analysis [33–36], industrial park competitiveness [37], and e-commerce customer behavior [38], studies on economic modeling [39, 40] and information management systems in spatial planning [41, 42] provide a broader context for analyzing regional labor markets.

While the Ukrainian regional labor market faces challenges, existing research offers valuable insights. Studies [43] on social tensions and [44] on war's impact on human capital illuminate potential vulnerabilities. Understanding migration patterns analyzed in [45–47] is crucial for forecasting labor supply and demand. The importance of regional skills development highlighted in [48] aligns with the need for robust forecasting models explored in [49].

2.2 Multidimensional Ranking Methods in Economics: Ideas and Realization

Taxonomy analysis is the science of how to organize and name complex systems of reality, such as living things, places, languages, and cultures. The purpose of taxonomy analysis is to establish and explain the criteria and structure of classification groups, their hierarchy, relationship, size. Figure 1 shows the calculation of the taxonomic analysis, which consists of the following stages:

Stage 1. The first step in determining a taxonomic indicator is the creation of a matrix of observations X of dimension (m * n), where the values of the characteristics (characteristics) of multidimensional units are stored.

Stage 2. To standardize the values of the elements of the observation matrix, we determine the average value for each indicator.

Standardization of indicators takes place according to formula (1):

$$y_{ik} = \frac{x_{ik} - m_k}{\sigma_k}, \quad i = 1, \ldots, m, \quad k = 1, \ldots, n \tag{1}$$

where

y_{ik} is the standardized value,
m the number of rows of the matrix,
n the number of signs of each statistical unit,
k sign number,
x_{ik} sign value,
σ_k is the standard deviation of the characteristic number k,
m_k assessment of the mathematical expectation of the sign value x_{ik}.

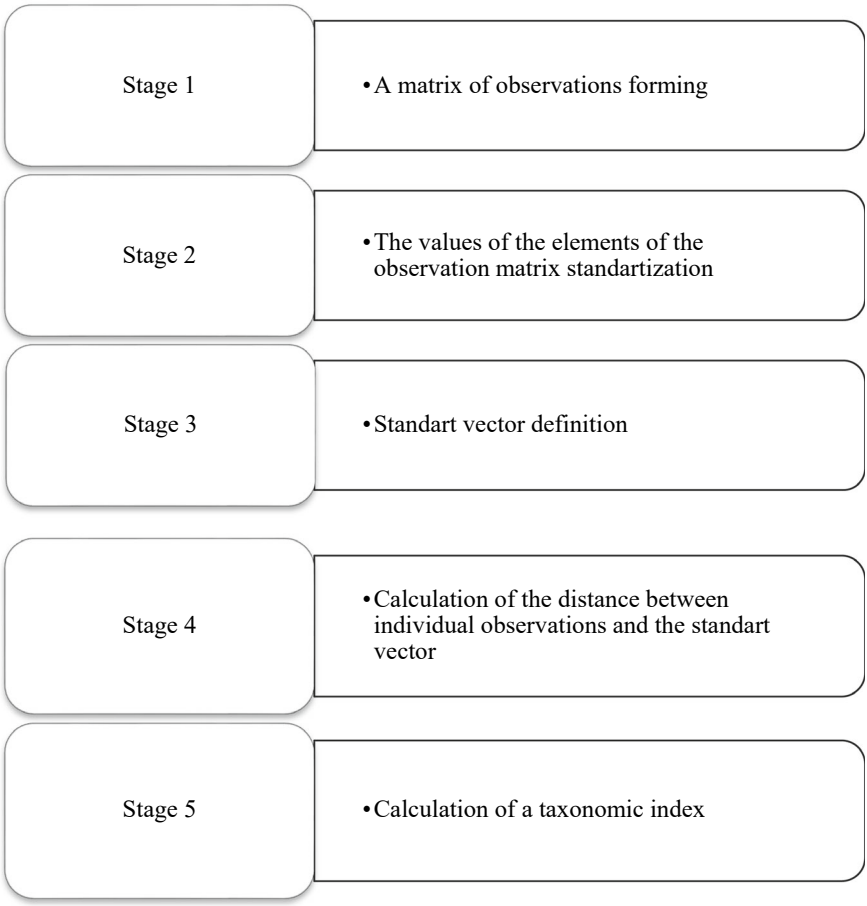

Fig. 1 Algorithm of taxonomic indicator calculation

The standard deviation of indicators is calculated according to the following formula:

$$\sigma = \sqrt{\frac{\sum_{k=1}^{m} (x_{ik} - m_k)^2}{m}} \tag{2}$$

Stage 3. Next, you need to build a reference vector. For this, it is necessary to divide the signs into stimulators and destimulators. Stimulants are indicators, the increase of which improves the overall assessment of the work of the research object. And destimulators, on the contrary, cause deterioration of work evaluation.

The following formulas are used to find them:

$$\begin{cases} y_{ik} = max\, \mathrm{x_{ik}}\ (stimulator) \\ y_{ik} = min\, x_{ik}\ (destimulator) \end{cases} \tag{3}$$

Stage 4. Next, to calculate the taxonomic index, it is necessary to determine the distance between individual observations and the reference vector. This is done according to the following formula:

$$C_{io} = \sqrt{\sum_{k=1}^{n} (y_{ik} - y_{0k})^2}, \quad i = 1, \ldots, m \tag{4}$$

Next, we will calculate the average distance according to the formula:

$$\overline{\mathrm{C}} = \frac{1}{m} \sum_{i\cdot=1}^{n} C_{i0} \tag{5}$$

The standard deviation is also calculated using the formula:

$$\sigma_0 = \sqrt{\frac{\sum_{k=1}^{m} \left(C_{i0} - \overline{\mathrm{C}}\right)^2}{m}} \tag{6}$$

Based on this, the maximum possible deviation from the standard (C_0) is calculated by the "rule of three sigma" according to the formula:

$$C_0 = \overline{C} + 3\,\sigma_0 \tag{7}$$

Next, the value of the intermediate indicator "level of development" is analyzed for each element Xi according to the formula:

$$P_i = \frac{C_{i0}}{C_0} \tag{8}$$

Stage 5. To determine the taxonomic indicator of the level of development of the system, the obtained distance is used as an initial value. Formula for calculation:

$$K_i = 1 - P_i \tag{9}$$

The taxonomic indicator constructed in this way synthetically characterizes the changes in the values of the features. Its most important feature is that we now have to deal with one synthetic feature that shows the direction and scale of changes in the processes described by a collection of an arbitrary number of input features that characterize the state and level of development of the economic system.

The integral assessment method consists in combining several individual indicators or criteria into one generalized (integral) indicator. This method allows you to get a comprehensive assessment of an object or phenomenon based on many parameters.

This approach is widely used in various fields such as economics, project management, ecology, social sciences, and others. It allows you to get a more objective and comprehensive assessment than the use of individual indicators.

For example, when evaluating the effectiveness of investments, various indicators are taken into account, such as profitability, risks, payback periods, socio-economic effects, etc. When analyzing product quality, technical characteristics, reliability, compliance with standards, and consumer feedback are taken into account.

Therefore, the integral evaluation method allows you to get a more accurate and comprehensive picture of the evaluated object or process (Fig. 2), taking into account various influencing factors.

Step 1. To determine the integral estimate, you must first create a dimension observation matrix (m * n), which stores the values of characteristics (signs) of multidimensional units.

Step 2. Since the criteria can have different units of measurement, it is necessary to normalize them to a single scale. For this, it is necessary to change the X matrix to the Z matrix. The elements of the Z matrix are calculated according to the formula

$$Z_{ij} = \frac{x_{ij} - \bar{x}_j}{\sigma_j} \tag{10}$$

where

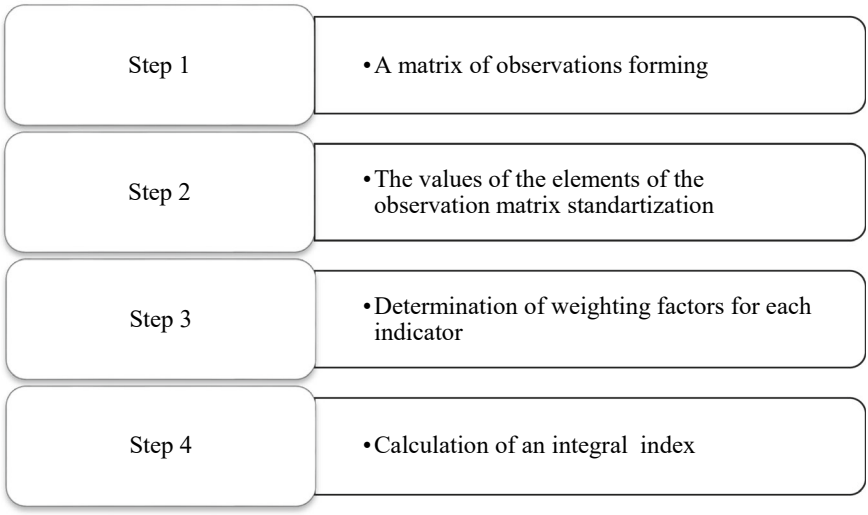

Fig. 2 Algorithm for calculating the integral estimate

$\overline{x}_j$ is the average value of the jth indicator,
σ_j is the root mean square deviation of the jth indicator.

Step 3. According to the integral assessment, we determine the weighting coefficients of the value for each block of indicators according to the determined stimulators and destimulators according to the following formulas

For indicators of stimulants:

$$P_i = \frac{\mathrm{Z} - \mathrm{Zmin}}{\mathrm{Zmax} - \mathrm{Zmin}} \tag{11}$$

For indicators of destimulators:

$$P_i = \frac{(\mathrm{Zmax} - \mathrm{Z})}{\mathrm{Zmax} - \mathrm{Zmin}} \tag{12}$$

Xmax; Xmin—maximum and minimum indicator value.

Step 4. The integral indicator is calculated according to the following formula:

$$\mathrm{I} = \frac{P_1 + P_2 + P_3 + \cdots + P_m}{m} \tag{13}$$

Therefore, integral evaluation is a powerful tool for analyzing complex systems and objects. It provides a comprehensive assessment, taking into account various aspects and indicators, which allows you to get a more complete and objective picture of the object or phenomenon. This simplifies the decision-making process and allows you to effectively compare different objects with each other.

3 Results

3.1 Quantitative Characteristics of Labor Markets by Region of Ukraine

Two methods were used in the investigation to analyze the labor market of Ukraine on regional level: taxonomic analysis and integral assessment.

1. The taxonomic method involves the classification and systematization of data by categories or classes, which will allow generalizing and structuring information about the labor market, revealing patterns and trends in its development.
2. The integral method involves combining various indicators into a single indicator, which will allow comparing the state of the labor market in different years and evaluating its dynamics.

Based on the principles of information availability, representativeness and reliability, a number of indicators were created according to our own approach to research.

Official statistical databases were used to form the matrix of input data, namely [50–52].

Eight indicators of Ukrainian regional labor markets for 24 regions of Ukraine for 2019–2021 were formed:

1. Average salary. This indicator reflects the average income of employees in a certain region, calculated as the arithmetic average of all payments received by employees. According to the results of calculations, the highest value of the indicator in 2019 was in Donetsk region (11,723), and the lowest in Chernivtsi (8073); in 2020 in Donetsk (12,652), and the least in Chernivtsi region (9156); in 2021, the highest value was also in Donetsk region, and the lowest in Kirovohrad region (11,178). A high level of average wages can attract skilled professionals, reduce labor migration, increase the purchasing power of the population, stimulate economic activity and raise the standard of living. Low average wages can lead to labor attrition, reduced employee motivation, and reduced economic activity.
2. The level of the employed population aged 15–70 (according to the ILO methodology). This indicator determines the share of the working-age population aged 15–70 that is employed. It is calculated as the ratio of the number of working people to the total population in the relevant age group. The value of the indicator above 55% indicates the effective use of labor resources, which has a positive effect on the economy of the region. Low employment may indicate economic problems, insufficient number of jobs or other negative factors. According to the results of the indicator calculation, Kharkiv region has been the leader for three years with an average indicator of 60.4%, and the lowest value of the indicator for 2019–2021 is in Volyn region—49.4%.
3. Rate of the population aged 15–70 (according to the ILO methodology). The highest value for 2019–2021 is in Luhansk region—15.9%, in turn, the lowest—in Kharkiv region (6.5%). A high level of unemployment can lead to an imbalance in the labor market, social tension, a decrease in the standard of living and economic stagnation. A low level of unemployment, on the contrary, indicates high employment and stability of the economy.
4. Workforce. This indicator indicates the share of people who are actively looking for work, but cannot find it. Analyzing the indicator, we can say that the highest value during 2019–2021 was in the Dnipropetrovsk region (1502.4), and the lowest in the Chernivtsi region—414.2. A large number of unemployed people can have negative consequences such as labor market imbalances, social tensions, lower living standards and economic stagnation. On the other hand, the low level of unemployment indicates high employment and stability of the economy.
5. The level of participation of the population in the labor force. This indicator reflects the percentage of the active population (both employed and unemployed) of the total population in the relevant age group. More than 60% of participation indicates the activity of the population in the economy, which contributes to economic development. A low level of participation may indicate demographic problems or low motivation to work. The highest indicator in 2019–2021 was in

Luhansk region—67.4%, and in Volyn region the value of the indicator for these years was the lowest—56%.

6. The wage fund for all employees. According to the results of the calculations, the highest value of the indicator is in the Dnipropetrovsk region—UAH 8471.08 on average for 2019–2021. The growth of the wage fund indicates an increase in the incomes of employees and improvement of working conditions, which has a positive effect on consumer demand and general economic development. The lowest value of the indicator in Chernivtsi region is 949.7. A decrease in the payroll may indicate economic difficulties or a reduction in the number of jobs.
7. The level of informal employment of the population. Informal employment covers jobs that are not regulated by the state and do not provide social guarantees. Odesa region has the highest indicator of the level of informal employment of the population (248), and the owner of the lowest value changed every year: in 2019, it was Poltava region (67.4); in 2020, Kyiv region (51.4); in 2021 in the Kirovohrad region (50.4). A high level of informal employment indicates insufficient development of the official labor market and can lead to social instability and economic losses for the state. The decrease in the level of informal employment indicates the development of the official economy and the improvement of social protection of workers.
8. Amount of salary arrears by region. This is a negative indicator that indicates financial problems of enterprises or organizations. The highest indicator during 2019–2020 was in Donetsk region (2019—535.14; 2020—727.2), and in 2021 Dnipropetrovsk region became the leader—709.15. Chernivtsi region had the lowest value in three years (2019—0.29; 2020—3.71; 2021—98.85). A high level of indebtedness can lead to a decrease in the motivation of employees, social conflicts and a deterioration in the standard of living of the population. The decrease in debt indicates the improvement of the financial situation and the employers' fulfillment of their obligations to the employees.

3.2 Taxonomic Analysis of Regional Labor Markets in Ukraine

Analyzing the works of scientists, one can note the advantages of taxonomic analysis when studying the development of regions. First, this method allows you to combine various information into one effective indicator. Secondly, it allows the use of a large number of indicators, even if they have different units of measurement. Thirdly, taxonomic analysis allows to supplement the research with additional indicators. Examining this method in more detail on the example of regions of the country, the following main indicators of the labor market can be distinguished. Primary indicators of the labor market are indicated in Table 1.

Currently, indicators describing various properties of objects in matrix X (Table 1) may have different distributions of values and different dimensions. Therefore, the next stage will be the standardization of signs of the transition to normalized

Table 1 Input data for taxonomic analysis primary labor market indicators used in the analysis

Indicator designation	Indicator	Unit of measurement
X1	Average salary of employees per month	UAH
X2	Employment rate of the population aged 15–70	%
X3	The unemployment rate of the population aged 15–70	%
X4	Workforce	persons
X5	The level of participation of the population in the labor force	%
X6	Wage fund for all employees	UAH
X7	The level of informal employment of the population	%
X8	Amount of salary arrears by region	persons

dimensionless values according to the formula (1):

$$y_{11} = \frac{10{,}300.67 - 10{,}280.8}{933.87} = 0.02; \quad y_{12} = \frac{56.2 - 55.4}{2.6} = 0.31;$$
$$y_{13} = \frac{10.7 - 10.32}{2.34} = 0.17; \quad y_{14} = \frac{710.7 - 298.42}{672.47} = 0.13;$$
$$y_{15} = \frac{62.9 - 1.78}{2.3} = 0.47; \quad y_{16} = \frac{2614.2 - 2786.67}{1836.62} = -0.09;$$
$$y_{17} = \frac{184.9 - 127.69}{57.05} = 1; \quad y_{18} = \frac{15.84 - 125.07}{183.1} = -0.6.$$

For example, the standardization of indicators of the Vinnytsia region for 2020 was considered.

For further analysis, a standard vector is formed based on the division of labor market indicators, taking into account their impact on the level of development of the object under study. Allocate:

1. Indicators-stimulators (the value of which should go to the maximum) which include: the level of the employed population aged 15–70 (according to the ILO methodology); workforce; the level of participation of the population in the labor force; wage fund for all employees, average salary of employees.
2. Indicators-destimulators (the value of which should go to the minimum) which include: the unemployment rate of the population aged 15–70 (according to the ILO methodology); the level of informal employment of the population; c account of salary arrears by region.

To determine the taxonomic index of the regions based on the selected characteristics, standardized characteristics of the benchmark of development related to the labor market in Ukraine are used. Therefore, the coordinates of the reference vector of the labor market will be as follows:

Table 2 Calculation results of average distance, standard deviation and maximum possible deviation

	2019	2020	2021
Average distance	6.11	6.20	6.24
Deviation	1.07	1.24	1.07
Max permissible deviation	9.32	9.92	9.44

$$y_{0(2019)} = (-1.17;\ 1.73;\ -1.34;\ 2.76;\ 2.03;\ 3.26;\ -1.32;\ -0.71)$$

$$y_{0(2020)} = (-1.20;\ 1.73;\ -1.78;\ 2.76;\ 2.08;\ 3.23;\ -1.34;\ -0.66)$$

$$y_{0(2021)} = (-1.22;\ 1.78;\ -1.69;\ 2.76;\ 2.16;\ 3.18;\ -1.20;\ -1.00)$$

Using formula (4), the distance between individual elements of the matrix of standardized values and the reference vector is calculated.

The next stage will be the calculation of the average distance according to the formula (5).

Next, the standard deviation is calculated according to the formula (6).

Based on this, the maximum possible deviation from the standard (C_0) is calculated according to the formula (7). Table 2 shows the results of all calculations.

Next, the value of the intermediate indicator "level of development" is analyzed for each element Xi according to the formula (8).

$$P_1 = \frac{5.78}{9.92} = 0.58; \quad P_2 = \frac{8.73}{9.92} = 0.88; \quad P_3 = \frac{4.82}{9.92} = 0.49;$$
$$P_4 = \frac{9.21}{9.92} = 0.93; \quad P_5 = \frac{5.97}{9.92} = 0.6.$$

And the final stage of the analysis of regional labor markets is the calculation of the taxonomy coefficient (K_i) according to the formula (9):

$$K_1 = 1 - 0.58 = 0.42;\ K_2 = 1 - 0.88 = 0.12;\ K_3 = 1 - 0.49 = 0.51;$$
$$K_4 = 1 - 0.93 = 0.07;\ K_5 = 1 - 0.6 = 0.4.$$

An example was given of the calculation of the value of the intermediate "level of development" and the taxonomy coefficient for the first five regions of 2020, then by analogy the calculation of all regions is carried out.

3.3 Integral Assessment of Regional Markets of Ukraine

The indicators that will be evaluated by the integral method are the same, as for taxonomic analysis.

Since each of these indicators is in different units of measurement, in order to carry out an integral assessment, it is necessary to reduce them to a one-dimensional form by performing a mathematical normalization procedure according to the formula (the calculation is carried out based on the values of the indicator in 2020):

$$Z_{11} = \frac{10{,}300.67 - 10{,}280.8}{933.87} = 0.02; \quad Z_{12} = \frac{56.2 - 55.4}{2.6} = 0.31;$$
$$Z_{13} = \frac{10.7 - 10.32}{2.34} = 0.17; \quad Z_{14} = \frac{710.7 - 298.42}{672.47} = 0.13;$$
$$Z_{15} = \frac{62.9 - 1.78}{2.3} = 0.47; \quad Z_{16} = \frac{2614.2 - 2786.67}{1836.62} = -0.09;$$
$$Z_{17} = \frac{184.9 - 127.69}{57.05} = 1; \quad Z_{18} = \frac{15.84 - 125.07}{183.1} = -0.6.$$

An example of calculating the normalization of indicators was carried out in the Vinnytsia region, the following indicators are calculated in the same way.

The next stage is the calculation of the weighting coefficients of each indicator. But before that, it is necessary to divide them into stimulating indicators and destimulating indicators. The division of indicators into stimulators and destimulators is shown in Table 3.

The division was carried out because the weighting factors are calculated according to different formulas.

To begin with, you need to choose the largest and smallest value of the indicator: Z1max = 2.54; Z1min = − 1.2.

Indicators-stimulators according to the formula (11):

$$P_1 = \frac{0.02 - (-1.2)}{2.54 - (-1.2)} = 0.67; \quad P_3 = \frac{0.17 - (-1.2)}{2.54 - (-1.2)} = 0.51;$$
$$P_7 = \frac{1 - (-1.2)}{2.54 - (-1.2)} = 0.34; \quad P_8 = \frac{-0.6 - (-1.2)}{2.54 - (-1.2)} = 0.98$$

Indicators-destimulators according to the formula (12):

Table 3 Division of indicators into stimulators and destimulators

Stimulators	Destimulators
The level of the employed population aged 15–70 (according to the ILO methodology)	The unemployment rate of the population aged 15–70 (according to the ILO methodology)
Workforce	The level of informal employment of the population
The level of participation of the population in the labor force	c of arrears for the payment of wages by region
Wage fund for all employees	
Average salary of employees	

$$P_2 = \frac{(2.54 - 0.31)}{2.54 - (-1.2)} = 0.66; \quad P_4 = \frac{(2.54 - 0.13)}{2.54 - (-1.2)} = 0.32;$$
$$P_5 = \frac{(2.54 - 0.47)}{2.54 - (-1.2)} = 0.65; \quad P_6 = \frac{(2.54 - (-0.09))}{2.54 - (-1.2)} = 0.21.$$

An example of calculations was carried out in the Vinnytsia region.
After that, the integral estimate is calculated according to formula (12).

$$\mathrm{I} = \frac{0.67 + 0.66 + 0.51 + 0.32 + 0.65 + 0.21 + 0.34 + 0.98}{8} = 0.54;$$

$$\mathrm{I} = \frac{0.96 + 0 + 0.32 + 0.07 + 0 + 0.07 + 0.72 + 0.95}{8} = 0.39;$$

$$\mathrm{I} = \frac{0.28 + 0.83 + 0.74 + 1 + 0.71 + 1 + 0.22 + 0.45}{8} = 0.65.$$

An example of the calculation of the integral assessment is carried out for the Vinnytsia, Volyn and Donetsk regions, the calculations of other regions are carried out by analogy.

4 Discussion

The results of the taxonomic analysis calculations for the regional labour markets of Ukraine are shown in Fig. 3.

Analyzing this graph, if we consider the results of each year separately, we can note that:

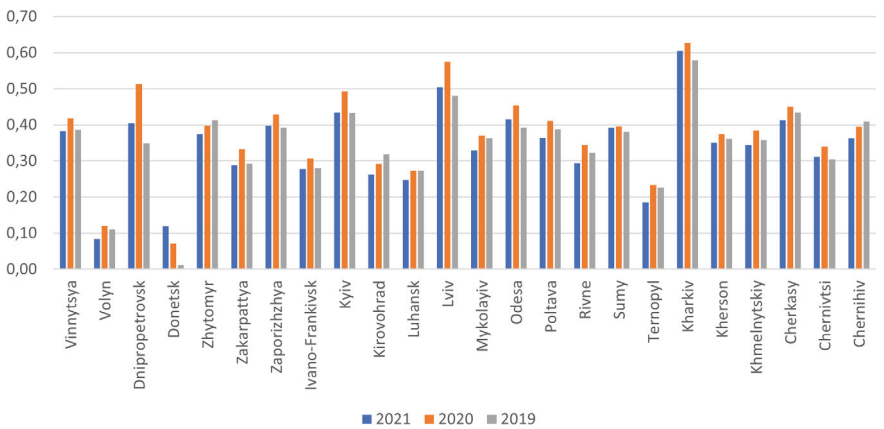

Fig. 3 Taxonomy coefficient for 2019–2021

- in 2019, the highest coefficient of taxonomy is observed in Kharkiv (0.58), Lviv (0.48), Kyiv (0.43) and Cherkasy (0.43) regions, and the lowest—in Donetsk (0.01), Volyn (0.07) and Ternopil (0.23)
- in 2020, the highest taxonomic coefficient is in Kharkiv (0.63), Lviv (0.57), Dnipropetrovsk (0.51) and Kyiv (0.49) regions, and the lowest coefficient is in such regions as Donetsk (0.07), Volynskyi (0.12) and Ternopilskyi (0.23)
- in 2021, the leaders are: Kharkiv region (0.60), Lviv region (0.50), Kyiv region (0.43) and Odesa region (0.42).

Therefore, if we consider the results of the taxonomy coefficient (Fig. 3), it can be noted that the absolute leaders from 2019 to 2021 are Kharkiv region, Lviv region and Kyiv region. In the regions, there is a certain balance between stimulating and disincentive factors in the functioning of the labor market. Among the stimulating factors, we can distinguish the number of the population, including the employed population, the level of work and the level of average wages. At the same time, there are factors that have a disincentive effect on the development of the labor market.

However, a critical situation has arisen in the Donetsk, Volyn and Ternopil regions, which requires state intervention and regulation of the labor market in these regions.

Therefore, taking into account the above-mentioned problems, it is necessary to formulate priority directions for reforming the national labor market in conditions of socio-economic instability. These areas include improving the wage system, increasing the demand for labor, directing state support to the development of small and medium-sized businesses, as well as making changes to the tax legislation regarding the development of entrepreneurship. To achieve these goals and to form full-fledged regional labor markets, as well as to increase the social prestige of labor, it is necessary to radically change the place of labor market problems in the system of priorities of the state socio-economic policy. It is also necessary to increase the amount of funding for activities related to solving the problem of employment and employment of the population.

The result of the integral index calculation for the regional labour markets of Ukraine is shown in Figs. 4, 5 and 6.

In 2019, such regions as Kharkiv (0.68), Chernihiv (0.67) and Cherkasy (0.64) had the highest integrated assessment of the labor market. These regions have had stable economic development due to various economic sectors such as industry, agriculture and services. A high level of employment and a low level of unemployment had a positive effect on the integral assessment of the labor market. The presence of leading educational institutions provided the labor market with qualified specialists, which contributed to high productivity and innovation. The attraction of both domestic and foreign investments contributed to the creation of new jobs and the development of economic infrastructure. The developed transport and social infrastructure created favorable conditions for business and life, which also had a positive effect on the labor market.

In turn, Donetsk (0.24), Volyn (0.44) oblasts have the lowest integrated assessment.

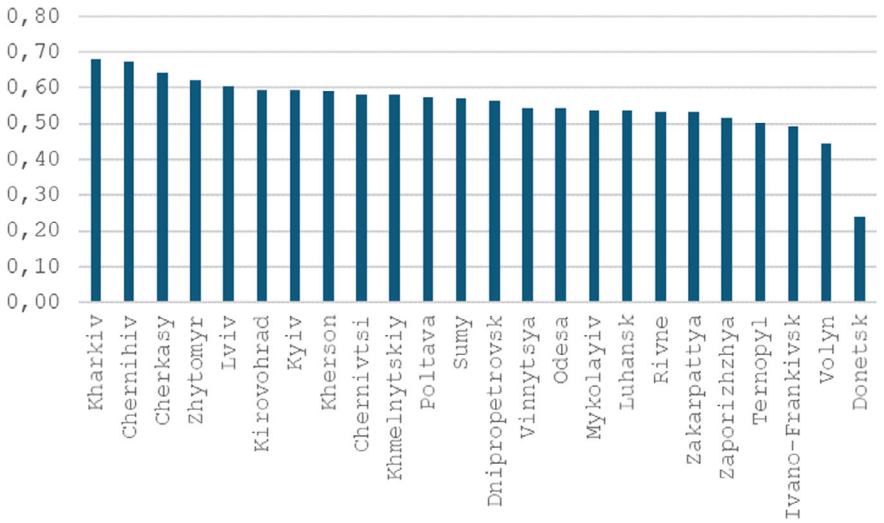

Fig. 4 Integrated assessment of regional labor markets of Ukraine for 2019

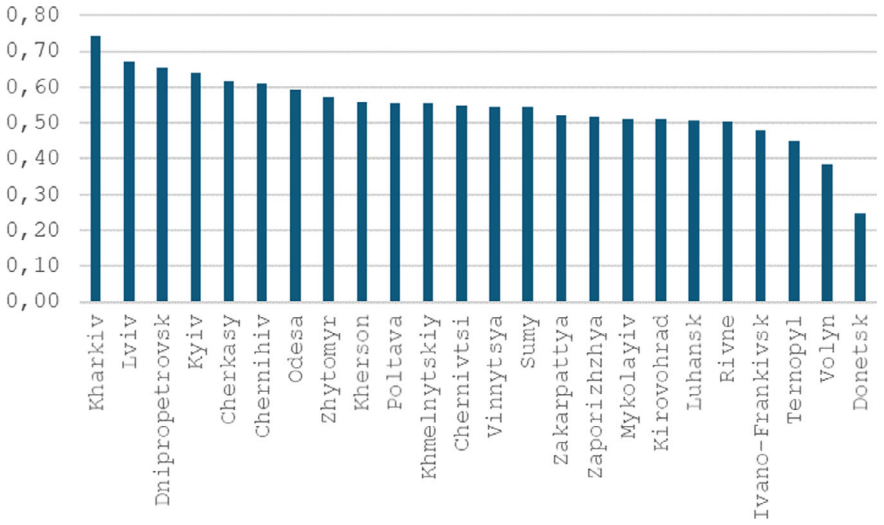

Fig. 5 Integrated assessment of labor market indicators in the regions of Ukraine for 2020

The prolonged occupation of Donetsk region led to the destruction of enterprises and loss of jobs. Volyn Oblast, for its part, had limited opportunities for economic development, as most jobs were in the agricultural sector, which did not provide stable growth. Both regions also faced the problem of insufficient infrastructure and investment, which limited business development and the creation of new jobs. This

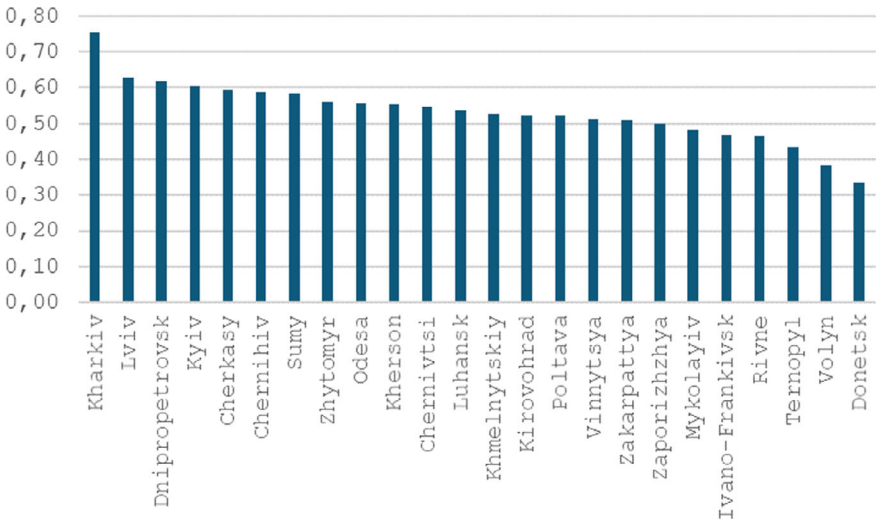

Fig. 6 Integrated assessment of labor market indicators of the regions of Ukraine for 2021

situation led to mass migration of the population from these areas, which reduced the workforce and the number of jobs (Fig. 5).

Having analyzed Fig. 4, the first three regions are the leaders of the overall integrated assessment of the labor market of Ukraine, namely Kharkiv (0.74), Lviv (0.67) and Dnipropetrovsk (0.65). These regions have significant economic potential and developed infrastructure, which contributes to the creation of new jobs. Kharkiv Oblast is known for its industrial and scientific potential, Lviv Oblast for the active development of the IT sector and tourism, and Dnipropetrovsk Oblast for industrial production and logistics.

And the lowest integrated assessment is in Donetsk (0.25), Volyn (0.39) and Ternopil (0.45) regions. The prolonged armed conflict in the east of Ukraine has seriously affected the economy and the labor market in the Donetsk region. Many businesses were destroyed or forced to close, causing significant job losses. Population migration due to hostilities has also affected the availability of skilled labor.

Regarding the economic difficulties in the Volyn and Ternopil regions, it should be noted that the economic structure of these regions is less developed compared to the industrial centers of Ukraine. The lack of large investments and infrastructure projects limits the opportunities for creating new jobs. The limited number of large enterprises that could provide a significant number of jobs also affects the activity of the labor market.

The figure is a graphical representation of the integrated assessment of the labor market of Ukraine for 2021 (Fig. 6).

Having received the overall integrated indicator of the labor market for each of the regions of Ukraine for the year 2021, it is possible to single out the leading region, which is Kharkiv region (0.757), the top 3 also includes Lviv region (0.630) and

Dnipropetrovsk region (0.619). The high indicators of the labor market in the Kharkiv, Lviv and Dnipropetrovsk regions in 2021 are due to a complex of economic, demographic, social, investment and infrastructure factors. These regions have a strong economic base, a lively business environment, a concentration of skilled workers and a developed infrastructure, which contributes to high employment and the dynamic development of the labor market [17].

And the lowest integrated assessment is in Donetsk (0.336), Volyn (0.382) and Ternopil (0.434) regions. Low labor market indicators in Donetsk, Volyn and Ternopil regions in 2021 are caused by complex factors, such as the impact of military conflicts, the economic structure of the region, demographic problems, low investment activity and weak infrastructure. These factors create unfavorable conditions for economic development and lead to low employment and low income levels in these regions.

The change of leaders in the rating of the integral assessment of the labor market between 2019 and 2020–2021 for the Chernihiv, Cherkasy, Lviv and Dnipropetrovsk regions can be explained by several key factors.

In 2019, Chernihiv and Cherkasy regions had high marks due to their agro-industrial sector. Chernihiv region received significant state investments in infrastructure and benefited from its proximity to Kyiv, which contributed to the development of logistics and business. Cherkasy region also had a developed agricultural sector and actively developed small and medium-sized businesses, which ensured a high level of employment.

During 2020–2021, Lviv and Dnipropetrovsk regions became leaders thanks to the rapid development of new sectors of the economy. The Lviv region was marked by significant growth in the IT sector, which created many high-paying jobs. In addition, Lviv recovered after the pandemic and became a center of domestic tourism, which contributed to an increase in employment in the service sector. The investment attractiveness of the Lviv region has increased due to its proximity to the EU borders, which has contributed to the inflow of foreign investments.

Dnipropetrovsk Oblast also demonstrated significant economic growth thanks to its industrial sector, which remained an important source of employment. A developed transport infrastructure, including a large railway hub and an international airport, contributed to the development of logistics and trade. Innovative projects and support for small and medium-sized businesses also contributed to the creation of new jobs.

In turn, the Kharkiv region maintains leadership in the integrated assessment of the labor market thanks to the combination of strong economic, scientific and educational resources. Continuous development of industry, active growth of the IT sector, investment attraction and developed infrastructure create a stable and favorable labor market. This allows the region to provide a high level of employment and attract a skilled workforce, which collectively supports its leadership for several years.

Donetsk, Volyn and Ternopil regions have the lowest integrated assessment due to persistent structural problems and limited opportunities for economic development. The Donetsk region suffered from the military conflict, which led to the destruction of industrial enterprises, infrastructure and high unemployment. Insecurity in the region also reduced its attractiveness for investors.

The Volyn region had limited economic development due to the predominantly agrarian focus of the economy. The absence of large industrial enterprises and the low diversification of the economy limited employment opportunities. Many of the working population left for work abroad, which led to a demographic outflow and a decrease in the number of active workers.

Ternopil Oblast also suffered from dependence on the agricultural sector, which was seasonal and led to unstable employment. Insufficient number of large investment projects and limited infrastructure made business development and creation of new jobs difficult. The lack of significant industrial centers and low investment attractiveness limited the possibilities of economic growth.

In general, Donetsk, Volyn and Ternopil regions had the lowest integrated labor market assessment due to persistent structural problems, insufficient investment and limited opportunities for economic development. Military conflict, agrarian orientation of the economy, population migration and insufficient infrastructure were the main factors complicating the situation on the labor market in these regions.

The dynamics of changes in the rating of the integrated assessment of the labor market reflect the influence of economic, social and political factors on the development of regions. The high performance of Chernihiv and Cherkasy regions in 2019 changed in favor of Lviv and Dnipropetrovsk regions in 2020–2021 due to their ability to quickly adapt to new conditions and actively develop new sectors of the economy. Low indicators of Donetsk, Volyn and Ternopil regions remain the result of persistent structural problems, insufficient investments and limited opportunities for economic development.

5 Conclusions

This study employed a two-pronged approach, combining taxonomic analysis and integral assessment, to investigate regional disparities and resilience in Ukrainian labor markets (2019–2021). The findings highlight significant variations across regions, with Kharkiv, Lviv, and Dnipropetrovsk demonstrating strong resilience through economic diversification, robust infrastructure, and skilled workforces. Conversely, Donetsk, Volyn, and Ternopil exhibited lower performance due to factors hindering adaptation, such as military conflict, overreliance on agriculture, and weak infrastructure.

The analysis reveals the interplay of economic, demographic, social, and infrastructural factors shaping regional labor market resilience. Regions with a diversified economic base, strong infrastructure, and a skilled workforce displayed greater capacity to adapt to changing economic realities. This highlights the importance of fostering these factors through regional economic policy.

Furthermore, the study underscores the dynamic nature of regional leadership. While Kharkiv maintained its top position throughout the period due to consistent

resilience, Lviv and Dnipropetrovsk exhibited remarkable adaptability by capitalizing on emerging economic opportunities. This underscores the potential for regional labor markets to improve through strategic adaptation.

The employed methods proved to be effective tools for analyzing regional labor markets. Taxonomic analysis facilitated the identification of regional trends, while integral assessment provided insights into the interconnectedness of factors influencing labor market resilience. These methods can be valuable assets for future research and policy development aimed at fostering resilience and reducing regional disparities in Ukrainian labor markets.

In conclusion, this study offers valuable insights into the dynamics of resilience and disparities within Ukrainian regional labor markets. By promoting economic diversification, infrastructure development, and workforce skills development, policymakers can create a more balanced and adaptable regional landscape, ultimately contributing to a more resilient national economy.

Data Availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest There is no conflict of interest regarding this paper.

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Climate-Resilient Building, Municipal Heat Planning, and the Contribution of District Heating

Melanie Jablonski, Matthias Jablonski, Peter Markovič, and Milos Hitka

Abstract This article examines the significance of climate-resilient building as a key strategy to address the challenges posed by climate change in the construction industry. A comprehensive methodology was employed, based on qualitative analysis and systematic data evaluation using MAXQDA, expert interviews, an expert survey, and a literature review in the Web of Science and Scopus databases. Climate-resilient building aims to design buildings and infrastructure that can withstand extreme weather conditions, minimize energy consumption, and reduce CO_2 emissions. A central focus of this endeavor is the municipal heat planning law, which aims to promote systematic and sustainable heat supply planning in German cities and municipalities. By promoting renewable energy and increasing supply security, the law aims to enhance the resilience of construction projects to climate change. A key component of this strategy is the integration of district heating as a tool to improve energy efficiency and reduce greenhouse gas emissions. The findings show that district heating has the potential to reduce energy consumption and dependency on fossil fuels through centralized heat generation and distribution. The article explores the advantages and challenges of district heating, including high investment costs and the need to switch to renewable energy sources. Additionally, case studies of successful implementations, such as the Vauban district in Freiburg and HafenCity in Hamburg, are presented, demonstrating how district heating can be

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effectively integrated into climate-resilient building projects. Political and economic frameworks are identified as crucial factors for the successful implementation of such projects. The article concludes with an outlook on future developments and trends in climate-resilient building and underscores the importance of collaboration between governments, businesses, and research institutions to promote a sustainable and future-proof construction industry.

Keywords Climate-resilient building · District heating · Energy efficiency · CO_2 emissions · Municipal heat planning law · Renewable energy · Sustainable construction industry

1 Introduction

Climate change represents one of the greatest challenges of the twenty-first century, requiring comprehensive adjustments in all areas of society. The construction industry is particularly affected, as it contributes significantly to greenhouse gas emissions and is directly impacted by the effects of climate change. Extreme weather events, rising temperatures, and altered precipitation patterns necessitate a rethinking in construction planning and execution. In this context, the concept of climate-resilient building is gaining importance. Climate-resilient building encompasses strategies and technologies aimed at designing buildings and infrastructure to withstand the challenges of climate change while minimizing their environmental impact.

A central aspect of climate-resilient building is the planning and implementation of sustainable heat supply concepts. Germany faces several challenges in this regard, which hinder efficient progress in climate-compatible construction. One initial hurdle is the significantly low homeownership rate compared to the EU average. In 2022, this rate stood at about 49.5%—less than half of the population lives in their own homes [21]. In the top seven metropolises, it is even only 20% [19]. The EU average is approximately 70% [17]. On the other hand, Germany is the strongest economy in the European Union, contributing significantly to the EU's economic stability with a GDP of 4.0 trillion USD in 2023 [12, 20]. But where does this disparity between high economic power and low homeownership rate come from? Reasons can be found in a strong rental culture, high property prices, and strict financing conditions. To transition from a fossil-based to a climate-resilient construction industry, it is essential to address both homeowners and tenants in almost equal measure. The existing investment dilemma is currently exacerbated by rising construction costs, significantly higher interest rates, and stricter regulations—profitability and, consequently, the demand for investment continue to decline. At the same time, the demand for affordable housing is increasing [25]. In this area of tension, the new municipal heat planning law (WPG) and the use of district heating are expected to make a crucial contribution in the future. The goal is to generate sustainable value in energy efficiency and sovereignty through green district heating. The municipal

heat planning law aims to ensure systematic and long-term heat supply planning in cities and larger municipalities to increase both supply security and sustainability. District heating offers a promising solution to increase energy efficiency and reduce CO_2 emissions in this context.

2 Objectives and Tasks

This article is dedicated to a comprehensive examination of various aspects of climate-resilient building and highlights the central importance of the municipal heat planning law and district heating. These elements are seen as key factors in promoting sustainable and resilient construction that can meet the challenges of climate change. By analyzing and discussing political and economic frameworks, the article provides valuable insights into the prerequisites necessary for the successful implementation of such projects. The focus is on discussing both theoretical and practical approaches aimed at strengthening the resilience of buildings to increasing climatic changes. Particular attention is paid to integrating sustainable heat supply solutions that not only improve energy efficiency but also significantly reduce CO_2 emissions. This discussion is conducted at a scientific level and considers the latest research findings and technological developments in this field. The municipal heat planning law is viewed as a crucial instrument that paves the way for systematic and long-term heat supply in urban areas. It promotes the use of renewable energy and supports municipalities in developing tailored strategies to increase energy efficiency and reduce dependence on fossil fuels. In this context, district heating plays a decisive role as an efficient and environmentally friendly solution for meeting the heating needs of large populations.

Additionally, the article will examine the political and economic frameworks that influence the implementation of climate-resilient construction projects. It will show how funding programs and legal regulations can be utilized to promote innovation and overcome obstacles. At the same time, the importance of collaboration between various stakeholders—including governments, businesses, and research institutions—will be emphasized to harness synergies and develop a coherent strategy for promoting climate-resilient building. The aim of the article is to provide a comprehensive picture of the current challenges and opportunities in climate-resilient building and to present practical solutions that can contribute to achieving climate goals. The focus will not only be on technological innovations but also on the necessity of a supportive political and economic environment to facilitate the transition to a sustainable construction industry.

3 Materials and Methods

The research design of this study is based on a qualitative and analytical approach. Initially, secondary data from the relatively young field of research were systematically and rule-based collected using the Kuckartz method with the help of MAXQDA and then presented in a compressed form. The case studies of the Vauban district in Freiburg and HafenCity in Hamburg illustrate the successful integration of green district heating in Germany. In addition, the literature review focused on the Web of Science and Scopus databases, specifically searching for publications from the past five years on climate-resilient building and district heating integration. Further data were obtained from various public and collected sources, including national statistics on energy efficiency and CO_2 emissions. It became evident that this topic has not yet been sufficiently addressed in research.

The lack of practical relevance particularly hindered a detailed representation of the scope for action concerning climate-resilient building and the contribution of district heating. Therefore, the following research questions aim to contribute to expanding the scientific knowledge base.

Research Question 1: What role does the municipal heat planning law play in implementing climate-resilient construction projects in Germany?

Research Question 2: To what extent can the integration of district heating contribute to reducing CO_2 emissions and increasing energy efficiency?

These research questions focus on the political and economic frameworks necessary for the successful implementation of climate-resilient construction projects in Germany. They investigate the effectiveness of the municipal heat planning law in promoting sustainable heat supply concepts and examine the potential and challenges of integrating district heating as a means to increase energy efficiency and reduce dependence on fossil fuels. These research questions address key issues of climate-resilient building and allow for an in-depth analysis of the various factors critical to the development and implementation of sustainable construction projects.

To comprehensively answer the research questions, this article employs a variety of empirical research methods. Initially, expert interviews were conducted with professionals from the energy industry and urban planning. The selection of experts was based on their extensive experience in climate-resilient construction projects. A total of 26 interviews were conducted based on a semi-structured guide. Additionally, this technical article is based on a survey of 280 professionals from the energy industry, which helped to further substantiate the initial research findings. This survey included both closed-ended questions to gather quantitative data and open-ended questions to gain qualitative insights. The expert interviews and surveys were qualitatively analyzed using MAXQDA. The collected insights were verified.

4 Challenges of Climate Change for the Construction Industry

Climate change has profound effects on the built environment, ranging from rising average temperatures to more frequent and intense extreme weather events. These changes pose significant challenges to the construction industry, requiring the adaptation of existing construction methods and practices. Rising temperatures lead to an increased need for cooling in buildings, with consequences for energy consumption and operating costs. The issue of effective and sustainable air conditioning is currently challenging the industry. Geothermal systems or solar thermal air conditioning, for example, produce cooling from renewable energies but are limited in reducing heat loads. Here, it is hoped that future developments in this area will open up new opportunities to improve energy efficiency and reduce environmental impact.

At the same time, high temperatures can affect building materials and the structural integrity of buildings. More frequent extreme weather events, such as storms and floods, require increased resilience in buildings to minimize damage and losses. Adapting construction methods to changing climate conditions is essential to ensure the longevity and safety of buildings. Future sustainable construction must be designed to withstand extreme weather conditions to ensure the structural integrity and safety of buildings. This requires the use of modern technologies and materials specifically developed to address extreme events such as heavy rainfall, storms, and heatwaves. The use of waterproof concrete and barriers to isolate the spread of water contributes significantly to increasing the longevity and safety of people and buildings and is an important measure in the context of climate-resilient building.

The need to protect infrastructure and ensure the safety of residents during extreme weather events has changed in such a way that new high-strength building materials, innovative insulation systems, and smart building technologies are critical elements to meet these needs. An integrative approach that combines technical innovations with sustainable architecture is essential to realizing future-proof construction projects that are resilient to the challenges of climate change. The resilience of construction projects to climatic changes must be fundamentally increased. Resilient buildings are capable of adapting to changing climatic conditions and responding quickly to challenges.

This requires a holistic approach to construction planning and execution, where both the selection of appropriate building materials and the integration of energy-efficient technologies and sustainable supply concepts play a role. Climate-resilient buildings should be able to adapt to changing climate conditions while providing high living comfort and low environmental impact.

5 Principles of Climate-Resilient Building

Climate-resilient building is an approach that aims to design buildings and infrastructure to withstand the challenges of climate change. This includes both physical resilience to extreme weather conditions and the ability to minimize energy consumption and CO_2 emissions. The basic principles of climate-resilient building include:

Adaptability: Buildings should be designed flexibly to adapt to changing climate conditions. This can be achieved through modular construction methods and the possibility of retrofitting.

Energy Efficiency: Reducing energy consumption through the use of energy-efficient technologies and passive design strategies is a central aspect of climate-resilient building.

Sustainable Materials: The use of environmentally friendly and durable materials helps to reduce environmental impact and increase resilience to extreme weather conditions.

Integrated Planning: Holistic planning that considers all aspects of the building and its environment is crucial for the success of climate-resilient construction projects.

Another central aspect of climate-resilient building is the consideration of social and ecological sustainability. This approach emphasizes not only the physical adaptability of buildings but also the social resilience of communities living in them. By integrating green technologies and creating community spaces, climate-resilient building can make a significant contribution to improving quality of life.

Technological innovations and architectural design play a crucial role in implementing climate-resilient construction projects. The most important technologies and solutions include passive house concepts, green roofs and façade greening, rainwater management, and the integration of renewable energies. Adapting to climate change requires tailored solutions that account for the specific climatic conditions of a region. In cold climates, the focus is on insulation and efficient heating of buildings, while in hot regions, strategies for cooling and reducing solar radiation are the primary concern. In coastal or riverine regions, measures to protect against flooding and increase the structural resilience of buildings are particularly important. For Germany, with mostly temperate climate zones, the municipal heat planning law is intended to steer the transition to a more sustainable real estate industry.

5.1 Municipal Heat Planning as a Solution?

The municipal heat planning law was developed to ensure the long-term and sustainable heat supply in cities and municipalities. The goal is to reduce energy consumption and CO_2 emissions while ensuring supply security. The law requires municipalities to conduct heat planning based on a comprehensive analysis of current and future heat demand. Germany aims to achieve climate-neutral heating by 2045. Municipal heat planning provides information to citizens and businesses about whether connection to the district heating network is possible or if they should choose an alternative climate-friendly heating solution [5]. This includes identifying potential for renewable energy and developing strategies for efficiency improvement.

In the context of climate-resilient building, this enables coordinated and integrated heat supply planning. By identifying potential for renewable energy and developing strategies for efficiency improvement, municipalities can make their heat supply more sustainable and increase resilience to climate changes. Additionally, municipal heat planning provides the opportunity to harness synergies between different sectors and ensure a holistic approach to heat supply.

So much for the theory behind municipal heat planning. In practice, municipalities face several challenges in implementation. These include collecting and analyzing large amounts of data, considering diverse interests, and securing funding for measures. The latter, in particular, is likely to be a hurdle that many financially weak cities and municipalities can hardly overcome. Moreover, the federal government's debt brake hinders the long-term increase in funding. The path to successful heat planning will also depend on the provision of financial resources. At a time when high inflation and low growth are central to the economic debate, the energy crisis presents enormous challenges for the German economy. The dependence on fossil fuels and the simultaneous pressure to advance the energy transition create tensions. Thus, it is not surprising that many municipalities are turning to the integration of district heating as a tool for heat planning.

5.2 District Heating as a Tool for Municipal Heat Planning

Fundamentally, district heating offers an efficient way to provide heat to large populations. At the same time, district heating as a tool for municipal heat planning aims to reduce dependence on fossil fuels. For the financially weaker municipalities, it is therefore tempting to shift the required measures to the financially stronger energy suppliers. However, this assumes that district heating is largely generated from renewable energies. A significant portion of district heating production still relies on fossil fuels such as natural gas [23]. According to a 2022 study by the Federal Environment Agency, the share of renewable energies in district heating production overall was only about 20%. This includes both district heating networks that exclusively use

renewable energies and those that use a mix of renewable and conventional energy sources [5].

This promising solution for increasing energy efficiency and reducing greenhouse gas emissions has a significant drawback. To significantly reduce energy consumption in urban areas through district heating, the industry must convert its power plants to sustainable energy sources as quickly as possible. In this context, the experts surveyed see a combination of renewable energies, the use of unavoidable waste heat, heat pump technology in conjunction with green electricity, as well as gas-fired power plants with intelligent control and efficient energy storage as crucial for securing sustainably generated energy. The experts particularly emphasize the importance of renewable energy sources such as solar thermal, geothermal, water, and wind. Regarding the use of hydrogen in district heating, particularly in combined heat and power plants (CHP), they express concerns. Although hydrogen has great potential for climate-neutral energy production, there are significant uncertainties regarding its market ramp-up. The challenges lie mainly in developing efficient and sustainable production methods and in the storage and transport of hydrogen. To contribute to a sustainable energy transition in densely populated cities, a significant need for action initially exists. Besides the advantages, such as the energy efficiency of centralized production and distribution, high supply security, and the contribution to reducing CO_2 emissions in the case of integrating renewable energies, there are also disadvantages. Building a district heating network requires significant investment in infrastructure, which is economically challenging, especially in sparsely populated areas.

This urgently needed transition phase from district heating systems to renewable energies proves to be a complex and multifaceted process, bringing both technical and economic challenges. Traditionally, district heating in Germany is still largely generated from fossil fuels such as coal, oil, and gas, which significantly contribute to global warming due to their high CO_2 emissions [4]. The transition to renewable energy sources, such as biomass, solar thermal energy, and geothermal energy, is seen as a crucial measure to reduce greenhouse gas emissions and advance the energy transition. Integrating these renewable energies into existing district heating networks requires investment in infrastructure and adapting regulatory frameworks to create incentives for investing in more environmentally friendly technologies [14]. The shift to renewable energies is influenced not only by technological factors but also by social factors, such as public acceptance. Only if district heating meets a significant portion of the heat demand can the system be economically operated. In many places, this is intended to be regulated by a mandatory connection to district heating networks. The mandate at the municipal level ensures the economic viability of district heating networks and even utilization of the plants. However, this issue is somewhat controversial. Mandatory connection to district heating is associated with limited choice, potential cost increases, and the monopolistic position of providers, but above all, with limiting incentives for energy savings. In terms of costs, a comparison with other heating systems shows that district heating can often be a competitive option, but it strongly depends on local conditions and the respective district heating provider.

5.3 District Heating in Practice

In practice, the focus—as is often the case in this context—shifts to the Nordic countries. In Copenhagen, for example, district heating covers over 98% of the city's heat demand, primarily using renewable energies and waste heat from industry. The integration of renewable energies and the high energy efficiency of the plant have helped Copenhagen drastically reduce its CO_2 emissions. The city aims to be CO_2-neutral by 2025 [10]. Reykjavík, on the other hand, uses the geothermal energy of its unique geological location. Almost 90% of buildings are heated with geothermal district heating [16]. Stockholm also has ambitious goals for reducing CO_2 emissions and plans to be fossil-free by 2040. The district heating system plays a key role in this strategy [22]. Aarhus, as Denmark's second-largest city, has a district heating system based on waste incineration and biomass use. The city plans to increase the share of biomass and other renewable energies in the district heating system and reduce CO_2 emissions by 70% by 2030. Additionally, the city is experimenting with the use of heat pumps and solar thermal energy to further reduce fossil energy sources [1].

The Nordic countries thus demonstrate how district heating systems can be successfully used to reduce CO_2 emissions and promote energy efficiency. These systems combine various renewable energy sources and use technological innovations to ensure a sustainable and climate-resilient energy supply. The experiences of these countries can serve as a model for climate-resilient building worldwide.

In Germany, on the other hand, only about 14% of households are connected to district heating networks [13]. Moreover, the share of renewable energies within district heating production in Germany was only about 20% as of 2022 [13]. To support the German government's climate goals, this share must rise rapidly and significantly in the coming years. The government has set a goal of creating 100,000 new connections annually and tripling the connection rate to over 50%. German projects have long shown the success of district heating networks based on renewable energies. An example of the successful integration of district heating in climate-resilient construction projects is the Vauban district in Freiburg im Breisgau. The district was planned according to the principles of sustainability and energy efficiency and uses district heating from a nearby biomass plant. Another example can be found in Hamburg. HafenCity in Hamburg is one of the largest urban development projects in Europe and a prime example of sustainable urban development, where district heating plays a central role. HafenCity uses district heating, a significant portion of which comes from renewable energy sources. The share of renewable energies in HafenCity's district heating supply is about 92%. This mainly includes the use of industrial waste heat, biomass, and waste incineration, supplemented by geothermal and solar thermal systems. The environmental concept of HafenCity also relies on innovative technologies such as the integration of heat pumps and the use of solar thermal energy to further increase the share of renewable energies [3, 7, 24].

5.4 Opportunities and Challenges

Die summarizing the previous findings, it can be noted that the successful implementation of district heating systems has already contributed to a significant reduction in CO_2 emissions worldwide. District heating is also becoming a central element of municipal heat planning in Germany. However, a large part of district heating production still relies on fossil fuels, particularly natural gas, which increases vulnerability to price and supply risks. Modernizing existing district heating plants and switching to renewable energies will require significant infrastructure investments and be a correspondingly time-intensive endeavor. The question arises as to whether Germany is once again lagging behind the times.

According to experts, the urgently needed reduction of CO_2 emissions in the housing sector can only be realized through centralized heat production and distribution in urban areas. Accordingly, the implementation and expansion of district heating systems is an essential step towards climate protection. However, expanding district heating networks in Germany is a long-term project—the full integration into a sustainable energy system is not expected to be achieved until 2045. Short- and medium-term goals focus on expanding existing networks and increasing the integration of renewable energies. In the long term, the decarbonization of the heat supply is targeted to achieve national climate goals. However, the success of this endeavor will largely depend on political frameworks, available financial resources, technological innovations, and public acceptance [6].

Therefore, political frameworks are crucial in creating the legal and organizational framework for district heating development. The federal government is committed to supporting the expansion of renewable energies through targeted funding programs and regulatory measures. The financial aspect includes both public investments and private financing necessary to support the required infrastructural changes. However, as mentioned, the provision of funding is rendered absurd by the debt brake.

There is also room for improvement in the legal framework: The Wärmelieferverordnung (WärmeLV), in force since 2013, together with the Bürgerliches Gesetzbuch (BGB), stipulates that when new connections are made to the district heating network, operating costs must remain neutral. This regulation serves as a tenant protection instrument to ensure cost neutrality during the transition to district heating but has proven to be a significant sales obstacle in practice. In existing buildings, fewer and fewer new district heating connections are being made, while the total number of connections has only increased due to numerous new buildings with district heating. Due to the high investments in expansion and decarbonization, district heating cannot compete with gas in terms of price. The industry agrees that the targeted number of 100,000 new district heating connections cannot be achieved as long as WärmeLV continues to mandate cost neutrality. Furthermore, the available funding is not sufficient to lower district heating prices enough to achieve cost neutrality.

Nevertheless, using district heating in the sense of comprehensive climate-resilient construction offers significant potential for improving energy efficiency. By centrally

generating and distributing heat, energy consumption can be reduced, and dependence on fossil fuels minimized. Additionally, integrating renewable energies and waste heat allows for further reductions in CO_2 emissions. However, transitioning to renewable energies within district heating production must be accelerated and should be given top priority. Economic frameworks play a decisive role in implementing climate-resilient construction projects. Here, governments and municipalities can promote the development and implementation of such projects through legal requirements, funding programs, and incentives. The current market situation influences economic factors such as the costs of building materials and the use of sustainable technologies, affecting the feasibility and attractiveness of climate-resilient construction projects. The current situation, therefore, requires greater consideration of political responsibility.

Despite all the opportunities presented by municipal heat planning, one of the main criticisms remains the complexity and diversity of local conditions, which are not adequately addressed in a nationwide law. Municipalities differ significantly in terms of their geographical, demographic, and infrastructural conditions, which counteracts a uniform legal regulation. At the same time, introducing new regulations often requires extensive administrative processes, leading to increased effort that could further slow down planning and construction processes. In particular, smaller municipalities with limited personnel resources might struggle to efficiently meet the complex requirements of the law. Finally, there is a risk that the law may focus too heavily on technological solutions while neglecting social and cultural aspects. Climate-resilient construction projects require a holistic approach that considers both technical and social factors. A technocratic approach could undermine local population engagement and jeopardize public acceptance of the projects.

Successful implementation requires careful consideration of local conditions, reduction of bureaucratic hurdles, fair financial support, and the integration of social and technological aspects into planning processes. Only by overcoming these challenges can the law effectively contribute to creating sustainable and climate-resilient infrastructure.

6 Discussion

The new municipal heat planning law significantly emphasizes the role of municipalities. However, the question remains as to what extent individual municipalities can live up to this role. In practice, municipalities face major challenges in implementing the law. Collecting and analyzing extensive data, considering diverse interests, and financing measures pose immense hurdles, especially for financially weak municipalities. As Hainsch et al. highlighted, these challenges are part of the broader priorities and hurdles that the EU must address under its Green Deal to ensure a sustainable energy supply [11]. Despite this problem, the municipal heat planning law provides an essential basis for planning and implementing climate-resilient construction projects

by promoting a sustainable and forward-looking heat supply. Kemfert et al. emphasize the importance of financial incentives and investments to successfully implement the major green transformations required by the municipal heat planning law [15]. In this sense, the research question posed earlier can be answered as follows.

Research Question 1: What role does the municipal heat planning law play in implementing climate-resilient construction projects in Germany?

The municipal heat planning law plays a central role in implementing climate-resilient construction projects in Germany. This law aims to design the heat supply in cities and municipalities sustainably and long-term to reduce energy consumption and CO_2 emissions. Systematic planning will increase supply security, promote energy efficiency, and support climate resilience. Skjærseth emphasizes that political measures such as the heat planning law are crucial for the success of environmental and climate protection strategies, particularly in an ambitious context like the German energy transition [18]. However, to operate on a nationwide climate-neutral basis by 2045, significant efforts and substantial financial resources will be required in practice. The federal funding of around 500 million euros for the creation of heat plans can hardly be expected to have a significant impact given the magnitude of the challenge. Zell-Ziegler et al. discuss that introducing sufficiency measures in energy and climate plans is crucial to achieving the set climate goals despite limited financial resources [26]. Analyzing the municipal heat planning law has highlighted the importance of a strategic and systematic approach in promoting climate-resilient construction projects, particularly in reducing CO_2 emissions and increasing energy efficiency. A central component of such strategies can be the integration of district heating, which, due to its centralized structure and efficiency potential, could play a key role in implementing sustainable energy supply systems. In their study on sufficiency in European energy plans, Zell-Ziegler et al. also emphasize the relevance of efficient use of existing infrastructure, such as district heating systems, to achieve energy goals [26]. The second research question will be answered below to explore the extent to which district heating can contribute to reducing CO_2 emissions and improving energy efficiency in construction projects. It will also examine the challenges and opportunities associated with using district heating and the measures required to maximize its contribution to climate-resilient energy supply.

Research Question 2: To what extent can the integration of district heating contribute to reducing CO_2 emissions and increasing energy efficiency?

District heating offers significant potential for reducing CO_2 emissions and increasing energy efficiency in construction projects. It enables centralized heat generation and distribution, which offers considerable advantages over decentralized heating systems. Androniceanu and Sabie highlighted the strategic importance of district heating and green energy as key elements for Europe's sustainability goals [2]. Overall, district heating presents a promising opportunity to increase energy efficiency and reduce CO_2 emissions in construction projects. However, its integration into climate-resilient construction projects requires careful planning and investment, particularly to maximize the share of renewable energy. The expert consensus is that where possible, the responsibility will be transferred to district heating generation.

Skjærseth argues that such measures are particularly sensible in densely populated areas, where district heating can reach a broad tenant structure [18]. As previously described, district heating can be a viable strategy for supplying the general population, especially in densely populated areas. This approach virtually eliminates the initial investor dilemma and enables the broad tenant structure to be reached. However, transitioning to sustainable district heating production is a prerequisite for moving toward a sustainable energy future.

In addition to heat planning, the law also defines requirements for using renewable energy and unavoidable waste heat in heating networks. By 2030, heating networks must be supplied with 30% and by 2040 with 80% renewable energy or unavoidable waste heat. New heating networks must already have a share of 65% as of March 1, 2025 [6]. Therefore, energy suppliers are under increasing pressure, both from legal requirements and economic and societal expectations, to contribute to the energy transition. Kemfert et al. emphasize that without adequate financial support and clear legal requirements, such as those defined in the heat planning law, the necessary progress cannot be achieved [15].

A clear political will and corresponding legal frameworks are crucial to accelerate and facilitate the transition. Hainsch et al. stress that such frameworks are essential for the success of a large-scale energy transition in the context of the EU's Green Deal [11]. Energy suppliers should proactively embrace these developments to strengthen their role as future-oriented providers. Technological innovations play another key role by improving the efficiency and sustainability of district heating systems, such as through the use of smart grids, geothermal energy, or solar thermal systems.

7 Conclusion and Outlook

Climate-resilient building is a crucial component in addressing the challenges of climate change and offers diverse opportunities to improve energy efficiency and reduce environmental impact. As demonstrated in this work, the integration of the municipal heat planning law and district heating into the planning and implementation of such projects is critical to significantly enhancing the resilience and sustainability of buildings and infrastructure. However, implementation requires not only technological innovations but also strong political commitment and a supportive economic framework. In line with the findings of Hainsch et al. and Skjærseth, clear legal requirements and financial incentives must be created to support this transformation [11, 18].

The future of climate-resilient building will be shaped by technological innovations, political decisions, and societal developments. Key trends include the increased use of renewable energy, the further development of energy-efficient technologies, and the integration of digital solutions in construction planning and execution. The importance of sufficiency measures, as discussed by Zell-Ziegler et al., is increasingly being recognized to effectively achieve climate goals [26]. Furthermore, collaboration between various stakeholders, including governments, businesses, and research

institutions, is gaining importance. For successfully implementing climate-resilient construction projects, technological innovations are required and a supportive political and economic framework. Governments and municipalities play a crucial role in promoting and supporting such projects, while companies and research institutions can make a significant contribution through developing new technologies and solutions. As Kemfert et al. emphasize, sufficient financial resources and public acceptance are necessary to successfully transition to climate-neutral heating options [15].

Overall, climate-resilient building offers significant opportunities for sustainable and future-oriented development of our built environment. By collaborating with various stakeholders and integrating innovative technologies and practices, we can increase the resilience of our cities and communities to the challenges of climate change while making a significant contribution to climate protection. In terms of district heating, the advantages and disadvantages have been outlined. Its most significant advantage is reaching the general population. However, there is no universally optimal decarbonization path, as regions in Germany have different conditions and ownership structures. The ideal path must be determined locally by utilizing and incorporating all available heat sources on-site. Skjærseth's findings underscore that adapting to local conditions is crucial to fully realizing district heating's potential [18]. To fully realize district heating's potential as a climate-neutral heating option, more time, financial resources, and public acceptance are required. Additionally, smooth legal regulations are necessary, as emphasized by Hainsch et al. [11].

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Market Analytics as a Basis for Public Decision-Making

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Abstract Markets provide the framework for the development of economic relationships at various levels, including within local economies. A key factor contributing to economic welfare is the competition among business entities, whose competitiveness is influenced, in part, by public sector actions. This article explores the market elements relevant to the methods used by public authorities to detect and address non-competitive behavior among market participants. The authors outline the tools available to public authorities to foster and sustain robust competition within markets. Based on these tools, the article identifies key objects of market analysis pertinent to the public sector. Given that the public sector, as a component of an entity's external environment, can shape market conditions through policy decisions—both fostering competition and potentially encouraging non-competitive behavior—the article examines the impact of legal regulations on competition, highlighting potential focal points for market analysis.

Keywords Market · Analysis · Decision making · Public area · Market analysis

1 Introduction

The market, as a framework for economic relations, influences the behavior of both consumers and sellers through the interplay of economic forces. Market research can be approached from two perspectives: structural and behavioral. The structural approach emphasizes quantitative metrics, such as the number of market participants and their respective market shares, while the behavioral approach focuses on the decisions market participants make regarding their future actions. It is widely accepted that market structure significantly influences participant behavior, making structural analysis a crucial first step in predicting how market actors will behave.

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In this context, market analytics becomes essential for forecasting the future state of the market, both in terms of its structure and the potential actions of its participants.

For businesses, market analytics is vital for developing market strategies, identifying profitable opportunities, and establishing business relationships and partnerships. However, in the public sector, the focus shifts to utilizing market analytics as a foundation for informed decision-making. This includes developing regional development strategies, creating investment attraction programs, shaping tax policies that foster business growth, and promoting public–private partnerships to address socially important issues by leveraging the strengths of the private sector while maintaining public ownership.

2 Related Work

2.1 Market Behaviour of Actors: The Essence and Importance in the Public Sphere

For a long time, the post-Soviet countries were dominated by an administrative command system that did not provide for the emergence and development of business and the existence of a market economy. During this period, a system of state bodies was formed on the basis of centralisation and full control over all economic processes. However, the collapse of the Soviet system and the independence of the Soviet republics marked the beginning of not only democratisation, but also the restructuring of the public sphere, the choice of a course towards the formation and development of a market economy dominated by private property, the emergence of the concept of entrepreneurship, etc. In Ukraine, for example, the reform of the public sphere was accompanied by decentralisation processes, and as a result, the local economy as a component of the national economy has become important for the development of society. Local authorities have been given broader powers to attract economic resources at the local level to solve social and economic problems in certain areas.

Similarly to the European Union, in Ukraine, the actions of governmental authorities, local self-government bodies, administrative and economic management and control bodies in the event of anticompetitive practices are subject to prohibition [1]. Among the cases of prohibition of such actions defined by law are those related to:

- creation of new enterprises and entrepreneurship in general in any form;
- freedom to carry out economic activities, including the production, purchase or sale of products;
- freedom of business entities to decide whether to participate in associations;
- forcing business entities to commit concerted actions or concentration;
- forcing business entities to prioritise the conclusion of relevant contracts, supply or purchase of products with a specific circle of consumers or sellers;
- centralised distribution of goods;

- distribution of markets between entities on various grounds;
- creation of unfavourable or discriminatory business conditions;
- providing advantages that put a certain entity in a privileged position compared to its competitors;
- creation of unfavourable or discriminatory conditions for certain entities compared to its competitors, etc. [1].

In a market economy, a business entity has complete freedom of action. A prerequisite for competitive behaviour is equality before the law, the operation of market laws and the absence of market advantages not acquired through one's own efforts (for example, state assistance). Taking into account the signs of competitive relations [2, p. 10], it is possible to formulate the signs of competitive behaviour:

- Ensuring free access to resources;
- Forming an optimal cost structure as a condition for setting market prices;
- Diversification of activities aimed at minimising market risks and ensuring profitability, rather than establishing market control to enable abuse of market position;
- Management decisions are made in conjunction with the combination of the seller's interest and the needs of consumers;
- The purpose of the entities' activities is to obtain the highest possible profit by achieving the most favourable conditions for the production and sale of goods and services.

In contrast to competitive behaviour, non-competitive behaviour occurs when entities are limited in obtaining the desired profits. This limitation may be due to the absence of competitive advantages in the market, which are necessary to win in the competitive struggle in the markets. Entities choose illegal ways to achieve profitability that they can:

- depend directly on the actions of the entity itself (abuse of monopoly (dominant) position, restrictive and discriminatory activities, unfair competition);
- provide for joint actions with other entities (anticompetitive concerted actions, economic concentration);
- be stimulated by anti-competitive actions of the authorities and other bodies.

Given the powers of the authorities, both competitive and non-competitive behaviour can be encouraged through the policies they implement. For example, if the authorities and other bodies take actions prohibited by law, businesses will be encouraged to engage in all types of non-competitive behaviour. Even if such behaviour depends directly on the actions of the entity itself, the authorities may create an environment in which an entity with a monopoly or dominant position remains on the market through their own actions. Such a situation is possible when the authorities create obstacles to access to certain markets, and as a result, new entrants will not be able to enter the markets and compete with existing entities. Accordingly, restrictive and discriminatory activities are also closely related to markets: if the market is dominated by large enterprises and their associations, micro, small

and medium-sized businesses may be negatively affected by such large structures. Therefore, for harmonious development, it is important to maintain the presence of enterprises of different sizes in the market, each of which has its own advantages and can complement other enterprises to achieve the general public interest.

With regard to non-competitive behaviour based on joint actions with other entities (anticompetitive concerted actions, economic concentration), as noted above, the authorities are prohibited from forcing business entities to commit concerted actions or concentration, to take priority in concluding relevant contracts, supply or purchase products with a specific circle of consumers or sellers; to divide markets between entities on various grounds, etc.

When detecting non-competitive behaviour that depends directly on the actions of the entity itself, competition authorities first establish whether such behaviour could exist in the face of significant competition [3]. The objects of analysis depend on the method used:

- Comparative analysis [3]—involves comparing the behaviour of the subject under study with its behaviour in previous periods or the behaviour of other entities operating in similar competitive markets under similar conditions. The object of analysis is the strategic and tactical approaches to the entity's actions—activity in the market or restraint of activities in order to further increase its own capacity, free activity or creation of obstacles to the activities of existing or potential competitors in the market, etc.;
- The method of modelling qualitative characteristics [3]—the qualitative characteristics of the behaviour of the subject under study are compared with the modelled qualitative characteristics of its behaviour, which is assumed to take place in the conditions of significant competition in the market. As a starting point for building a qualitative model of the entity's behaviour under competitive conditions, compliance or non-compliance with the norms of sectoral state regulation is used. Accordingly, the object of analysis is the entity's behaviour, as in the case of the comparative analysis method, but the regulatory requirements in the relevant industry are taken into account and, based on the results of comparison with which, it is established whether the entity's behaviour deviates from such requirements. Often, the method of comparative analysis can reveal negative trends in the entity's behaviour, but conclusions about the legitimacy of such deviations can be formed using the method of modelling qualitative characteristics. This is due to the fact that state regulation of certain industries may cause corresponding changes in the behaviour of subjects. In this case, the conclusion is made that there are objective circumstances for certain behaviour and the behaviour of the entity will not be considered non-competitive, i.e., not only inconsistent with the laws of the market, the laws of competition in the market, but also with the norms of sectoral state regulation;
- Quantitative modelling method [3]—quantitative characteristics of the behaviour of the subject under study (e.g., cost, price, sales volumes) are compared with similar modelled characteristics of its behaviour, which is assumed to occur in the conditions of significant competition in the market. For example, profitability

analysis, econometric analysis of cost components, cost–benefit analysis, or other methods may be used.

Thus, in order to create the preconditions for competitive behaviour, the authorities should promote the existence of significant competition in the market, create fair rules of sectoral state regulation and monitor compliance with these rules on the basis of equality before the law. To promote the formation and existence of significant competition in the markets, the authorities may use the following tools:

- Supporting the market mechanism for the exit of inefficient enterprises from the market. Often, there are state-owned and municipal enterprises on the market that are inefficient or have low efficiency and for which there are no opportunities to improve their efficiency. Thus, artificially restraining the liquidation of such structures or their reorganisation leads to distortions of the market mechanism and irrational use of public resources;
- Implementation of business support tools [4]—organisation of spaces for trade (provide access to consumers using the possibilities of wide coverage during public events), provision of grants for business and organisation of the creation and operation of financing funds (refer to the financial mechanism and are intended for both newly created and existing businesses), introduction of dual education (the opportunity to participate in the practical training of future specialists, which will help solve the problem of labour resources
- Promotion of entrepreneurship [4]—aimed at solving certain problems in the activities of entities, namely: provision of office or production premises (shared spaces), information support on business creation and opportunities for its development (local business support institutions), joining efforts in a particular activity by several entities (support for existing and stimulation of creation of new cooperatives as a form of association of entities on the basis of self-government), combining entrepreneurial and social interests (
- Attracting new business and investment [4]—used in areas with low business activity, aimed at increasing the attractiveness of the territories for investment and business activity. The tools used include the following: access to land assets (provides access to one of the main production resources—land, through information on vacant land plots and their intended use, documentary support on the possibility of not only access to the land plot, but also its use), access to infrastructure (implemented through the restoration of abandoned industrial facilities, identification of the need to create new infrastructure facilities), attracting investors and partnership with business (implemented by the

In order for the authorities to choose a particular instrument to promote the formation and existence of significant competition in the markets, it is necessary to analyse different markets within the respective territories, in terms of various market indicators. The objects of market analysis from the public aspect of are shown in Fig. 1.

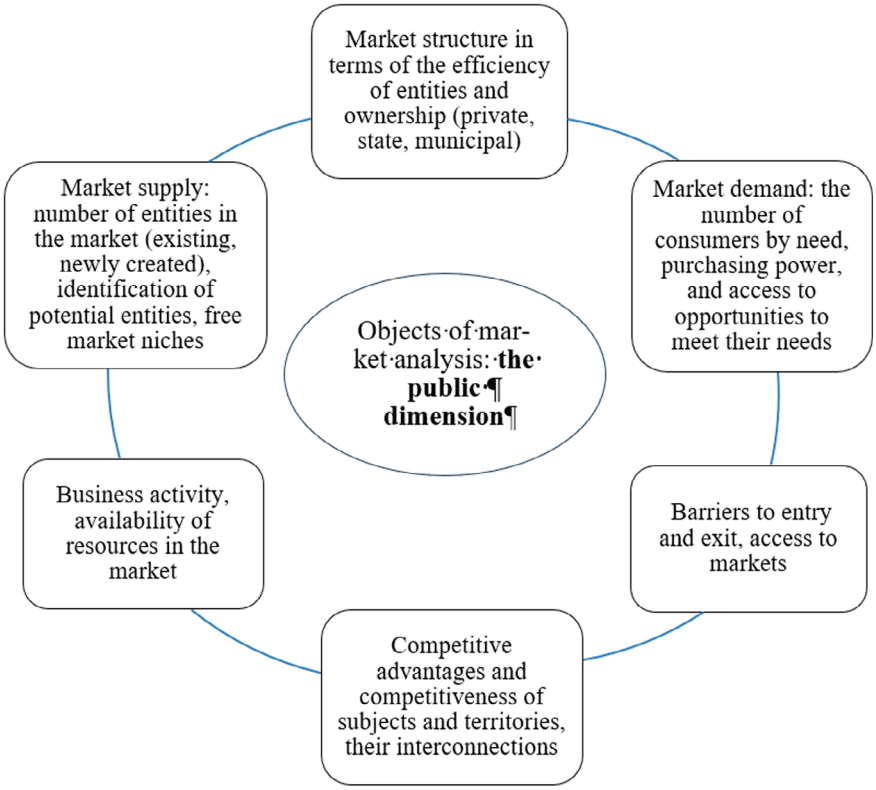

Fig. 1 Objects of market analysis: the public dimension

Competition, a fundamental element of a market economy, is inherently present in various aspects of market analysis. Public authorities, through both direct decision-making [5–7] and the development of regulatory policies, have the potential to impact competition negatively. Their actions can inadvertently distort market dynamics and disrupt the proper functioning of market mechanisms. Ukraine has implemented the approaches of the Organisation for Economic Co-operation and Development (OECD) to assess the impact on competition [8] of regulatory acts and draft acts, and developed relevant methodological recommendations [9].

The impact of a legal act on competition is divided into several categories [9]:

- "A"—limitation of the number or range of market participants:
  - *Granting exclusive rights*—requires a market structure analysis, which may determine whether there are many small, dispersed suppliers of products on the market. If exclusive rights are granted to a particular entity, it will not be subject to competitive pressure, and to reduce the negative effects on the market, such rights should be granted in exceptional cases and for a very short period of time. At the same time, frequent change of the recipient of exclusive

rights on a competitive basis will create preconditions for competition for market access;

- *Introduction of licences, permits or requirements for approval of business activities by the authorities*—requires an analysis of the ability of consumers to independently assess the quality of services and the qualifications of their providers in a particular market. If this capacity is low, the state introduces licensing, permits, etc., which creates a barrier to entry. Enterprises that have received a licence or permit are effectively protected from competition at the state level. At the same time, such enterprises are given opportunities to abuse their market position. When introducing licensing, the state must adhere to reasonable qualification requirements that should not be excessive, and to the balance of interests between protecting the interests of business entities and the interests of consumers;
- *Restrictions on the ability of individual entrepreneurs to sell goods or services*—the results of a sectoral market analysis are taken into account in terms of access to distribution channels, different types of operations for different entities, and the ability to sell products at competitive prices. In particular, in the area of public procurement, equality of access may be violated by the requirements of the public customer to involve a certain number of local enterprises in the execution of contracts, and the establishment of a mandatory minimum set of services;
- *Significant increase in the cost of entering or exiting the market*—the analysis of barriers to entry or exit may reveal obstacles that require significant costs for entities to overcome. For example, such barriers may be related to setting lower tariffs for incumbents than for new entrants, setting a standard technology for one of the new entrants that is not available to all other market participants, or setting high requirements for clean-up after the closure of production. If the introduction of certain market conditions results in insignificantly higher costs for all market participants, the conditions of competition will not change significantly. If, on the other hand, the introduction of certain changes does not increase the costs of all market participants, competition will be harmed. It is necessary to compare the costs of entities in connection with decision-making in the public sphere with the projected profitability and the projected growth of consumer prices;
- *Creation of geographical barriers to the movement of goods, works, services or investments*—it is necessary to analyse the relationship between the restriction of free movement of goods or services and increased concentration, market power of entities, and price increases. If there is such a direct link, it is necessary to determine the feasibility of the restriction in terms of political interests and the period of validity of such a restriction.

- "B"—limiting the ability of suppliers to compete:
  - *Limiting the ability of entrepreneurs to independently determine prices for goods and services*—based on the results of the market structure analysis, it

is possible to identify markets with a monopolistic structure (natural monopolies or housing and communal services markets) where price regulation is appropriate. However, the introduction of price regulation in markets with a competitive structure will have negative consequences for consumers and economic efficiency in general. If aggressive price competition and the presence of small businesses in the market are identified, minimum prices may be set to protect small businesses. In case of rapid growth of consumer prices and the emergence of market power of the dominant supplier, the state may introduce maximum prices;

- *Restrictions on the ability to advertise goods and services*—based on the results of an analysis of the consumption of goods with potentially negative consequences for human health and public welfare, such as cigarettes or alcohol, decisions may be made to restrict the advertising of the relevant goods;
- Setting quality standards that give unreasonable advantage to certain suppliers or standards higher than those chosen by sufficiently informed consumers—analysis of the dynamics of changes in the introduction of innovations, growth in consumer prices and the breadth of consumer choice will help identify the consequences of the introduction of high quality standards. In the case of negative interdependencies, the state's measures to ensure high quality of goods will lead to price increases, the exit of certain entities from the market, and, as a result, a decrease in competition;
- *Significant increase in costs of certain enterprises compared to others*—the object of analysis is the costs of some enterprises compared to others within the same market for their asymmetry. Such asymmetry is possible if the requirements for market participants that have just entered the market are relaxed compared to those already existing in the market, or if a market-wide requirement is introduced to use a certain technology that only a part of the enterprises possesses. As a result, not all market participants need to incur additional costs and invest in technology.

- "C"—a decrease in the motivation of business entities to compete actively:
  - *Introduction of self-regulation or joint regulation*—it is necessary to analyse structural changes in the market, changes in market power of entities, concentration processes for the period from the beginning of the introduction of self-regulation or joint regulation. For example, as a result of the actions of self-regulatory organisations, competition in the market may be reduced and certain entities may be encouraged to leave the market;
  - *Encouraging or requiring the publication of information on production, sales, costs or prices.* This action by the authorities may encourage the emergence of market collusion. In order to implement a publication requirement, it is necessary to identify the difficulty of comparing prices and making purchasing decisions for individual consumers. Such difficulties may occur in markets with widely differentiated products or varying volumes of services.

- "D"—restriction of access to information: common in the provision of medical services and pharmaceuticals. For example, by establishing lists of healthcare facilities to serve a certain category of consumers, the latter's right to freely choose a better quality service provider is restricted. For example, the ability of consumers to decide from whom to buy a product or service may be restricted, consumer mobility may be reduced by increasing the cost of replacing a supplier, and the information necessary to make a rational decision to purchase or sell goods may be restricted. In order to make decisions that do not harm competition, it is necessary to take into account the results of the analysis of market demand and supply of information on the possibility of meeting the needs in a better way at a competitive price. The mobility of consumers and their costs of switching from one supplier to another may also be subject to analysis.

2.2 Market Analysis Methods for Public Authorities

Market analysis requires a comprehensive approach that considers the sectoral structure of the economy and the role of a specific market within the regional and national economic landscape. It is essential to evaluate the market sector's share of the gross product, its development dynamics, and its contribution to value added and tax revenues. Special attention should be given to assessing the multiplier effect on other industries. Analyzing market concentration and determining the type of market structure are crucial for assessing the degree of monopolization and competition. Additionally, it is vital to identify the risks and barriers that may impede market development and impact the overall economic sustainability of the region.

The goals and objectives of market research, as well as the sequence of research and data analysis stages, depend on the context in which they are conducted and the type of decisions public authorities need to make. Generally, market research involves studying key indicators, market structure, and conditions; determining the current state and development trends; and analyzing components such as demand, supply, competition, customer satisfaction, capital attraction, and correlations with other markets.

The primary objectives of market analysis include:

- Assessing the state of the competitive environment
- Identifying issues that hinder competition development
- Evaluating demand conditions and parameters, including consumer behavior and decision-making processes [10, 11]
- Detecting violations of economic competition laws and instances of non-competitive behavior
- Formulating recommendations to enhance competition, stimulate business activity, and attract capital.

The methodology for market research incorporates both quantitative and qualitative tools, depending on the chosen approach. Quantitative methods focus on

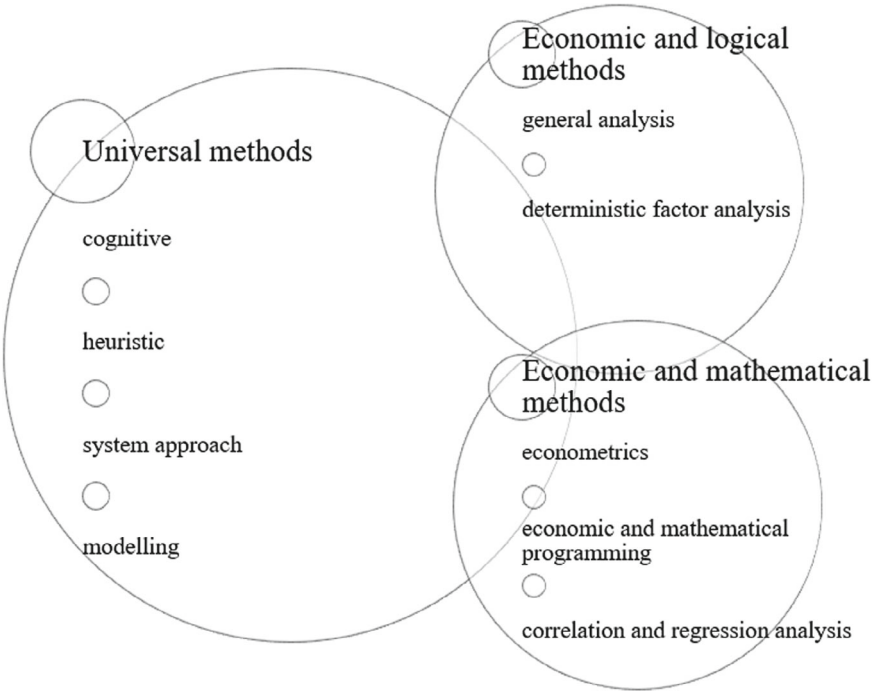

Fig. 2 Main groups of market analysis methods

analyzing numerical data, often presented through tables, graphs, and statistical models. In contrast, qualitative methods delve into consumer behavior, underlying motivations, and general market trends. These methods can be categorized [12, 13] into (see Fig. 2):

- Universal/general scientific;
- Specific (economic-logical and economic-mathematical).

Universal methods include cognitive methods (analysis, synthesis, induction, deduction), methods of systematic approach, heuristic methods (questionnaires, brainstorming, method of associations and analogies), and modelling. They can be used in both quantitative and qualitative analysis.

Economic and logical methods include methods of general analysis (comparison, grouping, averages, indices, graphical and analytical modeling, balance sheet methods, comprehensive assessment) and methods of deterministic factor analysis (elimination, logarithmic method, integral method).

Economic and mathematical methods include econometric methods, methods of economic and mathematical programming (alternative analysis, frontier analysis, elasticity analysis, optimization and equilibrium determination), correlation and regression analysis, factor, cluster and discriminant analysis, and aggregate analysis.

The specifics of different methods of market analysis determine their suitability for certain tasks; let us summarize some tasks for different methods of market analysis and provide examples of their application (see Table 1).

Thus, the results of market analysis can be used by public authorities at several levels:

- Market regulation. Government regulation of markets is an important tool for influencing the economy. By analyzing market trends, the authorities can develop and implement measures aimed at ensuring market stability, stimulating competition and protecting consumer rights. For example, in case of excessive market concentration of a certain product, the government may introduce antitrust measures.
- Financial support for business, territories and subsidies. Authorities can use market analysis to identify the most vulnerable sectors of the economy that require state support. This can be in the form of subsidies, low-interest loans, or tax breaks. Understanding market trends allows for more efficient allocation of financial resources and reduces cost risks.
- Social policy. Market analysis is also important for the development of social policy. In particular, it allows forecasting changes in the labor market and responding in a timely manner to possible increases in unemployment or labor shortages in certain industries. This can be useful for developing retraining and employment support programs.
- Investment policy. The results of market analysis allow public authorities to formulate an investment policy aimed at attracting both domestic and foreign investment in priority sectors of the economy. Analytics can be used to develop investor incentive strategies and create attractive conditions for investment.
- Regulatory measures during crises. In times of economic crisis, market analysis helps to identify the most affected industries and develop anti-crisis measures. These can include both tax incentives and measures to support small and medium-sized enterprises. For example, during the COVID-19 pandemic [14], market data analysis helped many governments develop business support programs and save jobs.

Market and territorial analysis, along with the decisions based on it, must always align with the overarching strategy and development model of the region. The goals of territorial management—or the key performance indicators (KPIs) for regional development—are directly influenced by the chosen development strategy. Adapting operational decisions to fit the regional development strategy is crucial for effective governance and sustainable territorial growth. This alignment ensures that short-term actions complement long-term goals, fostering balanced economic development, preventing conflicts between immediate measures and strategic plans, and enhancing the flexibility of management processes.

Here are some examples of how market analysis can inform public administration decisions.

For instance, market analysis has been effectively utilized in the public sector to study Ukraine's IT industry [15]. By examining the economic activities of enterprises

Table 1 Areas of application of market analysis methods

Types of methods	The tasks they are aimed at solving	Areas/examples of application in the public area
Cognitive methods (analysis, synthesis, induction, deduction)	Studying the conditions of general market equilibrium, determining parameters for different types of market structures	Determining the type of market structure for a particular market, developing state economic policy, and preparing the ground for economic reforms
Systems approach methods (system, structural and functional analysis)	Analysis of structural changes in the market, study of the level of market power of market participants, assessment of the impact of state policy on various sectors of the economy, SWOT and PEST (EL) analysis, determination of the relationship between the main groups of market participants and the overall supply chain	Regulation of markets, development of antitrust measures, planning the impact of state policy on various sectors of the economy, development of anti-crisis measures, application of antitrust measures and creation of conditions for the development of competition
Heuristic methods (questionnaires, brainstorming, method of associations and analogies)	Analyzing consumer behavior, identifying the complexity of price comparison by consumers and making purchase decisions, identifying investment climate factors	Optimization of state programs of information support for consumers, components of investment policy: development of strategies for attracting investment and creating attractive conditions for investment
Modeling (economic, mathematical, graphical)	Forecasting market dynamics, assessing the effectiveness of innovation and consumer demand characteristics, analyzing the relationship between the performance of market participants	Planning measures for regional economic development, stimulating innovation, price regulation, developing anti-crisis programs, budgeting and planning public investments
Comparison and grouping methods	Analysis of cost asymmetry among enterprises, comparison of costs of different market players	Improving the efficiency of state support for various sectors of the economy, implementing regulatory measures
Methods of deterministic factor analysis	Analysis of the dynamics of innovation and its impact on consumer prices, sectoral analysis of access to distribution channels	Developing economic development strategies, implementing business support tools, analyzing the availability of sales channels and price competition, identifying potential markets to be developed at the local level

(continued)

Table 1 (continued)

Types of methods	The tasks they are aimed at solving	Areas/examples of application in the public area
Econometric methods, methods of economic and mathematical programming	Studying market competition, market dynamics, demand elasticity, conducting a virtual monopoly test, assessing the impact of tax changes on economic activity	Regulation of new entrants, decision-making on mergers and acquisitions, prevention of anti-competitive actions, and development of national and regional tax policy
Analysis of populations	Assessment of the degree of market concentration and monopolization, study of the dynamics of changes in the market	Development and implementation of competition policy, assessment of concentration processes and market power after the introduction of regulation
Discriminant analysis	Identification of signs of violation of legislation on the protection of economic competition, determination of a dominant position	Implementing and comparing the effectiveness of regional development policies, taking steps to protect and promote competition in the markets
Methods of correlation and regression analysis	Study of the impact of international and regional trade barriers on markets, analysis of market concentration and its impact, forecasting of external factors such as legislative changes, new technologies or demographic trends	Implementation of antitrust measures, implementation of demand stimulation programs, distribution of budget support, and creation of a favorable investment climate
Cluster analysis	Analysis of sectoral distribution and ability to sell products at competitive prices	Segmentation of the labor market and development of employment programs for different population groups, determination of areas for targeting social assistance

and individual entrepreneurs in the IT sector from 2021 to 2023, key indicators such as the economic impact of the industry (both direct and indirect) and the number of jobs created (direct, indirect, and induced employment) were calculated for the relevant years (see Figs. 3 and 4 respectively). This analysis covered Ukraine as a whole, as well as key hubs with significant IT market shares.

In early 2022, the IT industry demonstrated growth across all regions. However, the onset of the full-scale invasion altered this trajectory, as it did for many sectors of the economy during wartime. The war introduced challenges such as the need to relocate companies, employees, and their families, as well as the mobilization of personnel into the Armed Forces and the emergence of new financial burdens like donations. Despite these challenges, the IT industry maintained its financial output in dollar terms, reaching USD 7.966 billion. However, the crisis year of 2022 brought

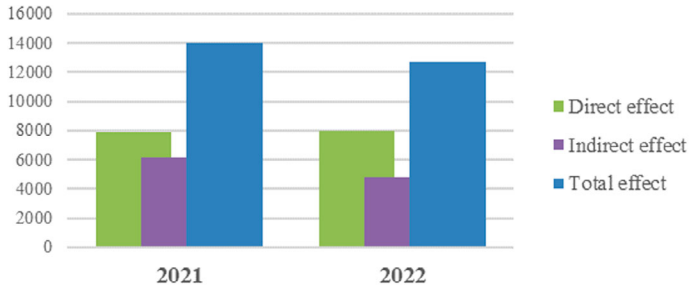

Fig. 3 The level of economic effects generated by the IT sector

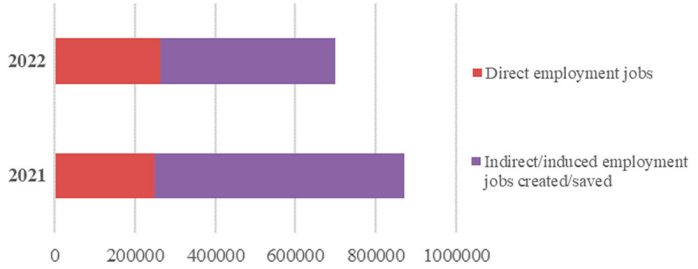

Fig. 4 Dynamics of job creation/saving by the IT industry in Ukraine

inflation (26%) and a devaluation of the hryvnia (34%), which adjusted the industry's financial results to UAH 257.6 billion, reflecting a 21% increase from the previous year. Tax revenues from the industry also rose by 16%, totaling UAH 20.56 billion. Additionally, the geographical distribution of IT market turnover shifted due to the migration of IT professionals away from regions close to the front lines.

The economic impact of Ukraine's IT industry enabled a comprehensive calculation of market turnover, accounting for indirect effects.

The remarkable growth in turnover and job creation, coupled with the industry's resilience during the economic crisis, positions the IT sector as an attractive investment opportunity for private and public entities. The mobility of production factors and the flexibility of business models further enhance the industry's appeal. The turnover calculations are presented in USD, reflecting the export-oriented nature of the IT market, where revenues are primarily reported in dollars. It is also essential to consider the changing income dynamics between IT professionals and domestic consumers and the relative returns on hryvnia versus dollar investments, particularly in light of the hryvnia's devaluation in 2022.

Those employed in the IT industry consume and supply goods and services to related industries, creating an additional increase in their own intermediate consumption. The impact of increased consumption creates induced and indirect employment, which in Ukraine can be estimated at 3.5 in 2021. The indicator declines to 2.66 in 2022, despite the currency devaluation, as the limiting factors of changes in the

structure of consumption and savings, primarily of those employed in the IT industry, come into play:

- The share of expenditures on imports (goods and services of foreign origin) increased due to the massive departure of Ukrainians abroad for temporary stay, including IT workers, whose share in Ukraine amounted to almost 20%, their family members dependent on IT workers, etc.
- The structure of consumer spending includes new items for the long term, namely donations and independent assistance to the Armed Forces, which in turn increases the share of imports.
- The NBU also took into account the diversified income of the IT sector as a result of the recruitment of some IT specialists to the Armed Forces.
- At the same time, spending on recreation services within Ukraine increased, helped by restrictions on men traveling abroad.
- Taking into account the long-term factor of influence, newcomers to the industry are also affected by the relocation of universities with IT specializations from the eastern regions and from regions close to the frontline.
- Decreased economic activity of businesses in the face of high risks and forced migration of Ukrainians from the labor force; increased qualification and regional disparities.

It should also be noted that, according to our calculations, the jobs created are generated in a larger share in industries where the average output per employee is higher than the average GDP per capita. This is also partly due to the overall reduction in the labor force in Ukraine in 2022, namely a 30% reduction from (17.4 to 12.5 million people), and the impact of additional factors: the exclusion of 1.45 refugees of working age, natural population aging, etc., which leads to an increase in the economic burden per employee and exceeds GDP per capita.

Understanding the influence of the IT market on the Ukrainian economy—particularly in terms of its economic impact—enables the government to fine-tune policies in key areas. This includes adjusting tax policy to better support the industry's growth and implementing more informed strategies for the mobilization of IT workers; overall, public policies may be developed for:

1. Support and advancement of the IT industry
    - Creating favorable conditions for investment: The government can develop and implement new programs to attract investment in the IT sector, in particular by introducing tax incentives and grants for IT companies, especially those developing new technologies.
    - Financial support: Ensure that IT companies have access to low-interest loans and continue preferential lending programs to support the sector during the crisis.
2. Relocation and support for IT companies and employees
    - Relocation support programs: Given the need to relocate IT companies and their employees from the war zone, it is advisable to create government support

programs that will ensure uninterrupted access to the necessary infrastructure, housing, and services in new regions.
- Restore and develop infrastructure in regions where IT companies are concentrated: The government should invest in infrastructure improvements in the regions hosting relocated companies to ensure stable operation of the industry.

3. Support for employment and training
   - Expansion of educational programs: Due to the relocation of higher education institutions and the need for qualified personnel, educational institutions specializing in IT education, including distance learning programs and refresher courses, should be developed and supported.
   - Job creation: Continue and expand government programs that stimulate the creation of new jobs in the IT sector, with a special focus on young professionals and IDPs and dual education.
4. Domestic market development and export support
   - Support for the export of IT services: As the IT sector is export-oriented, it is necessary to support exports by reducing bureaucratic barriers and providing advisory services for companies entering international markets.
   - Development of the domestic market: Develop strategies that would stimulate demand for IT products and services within the country, in particular through the introduction of public procurement for software development and digital services.
5. Stimulating the flexibility and adaptability of business models, adapting to economic challenges
   - Support for business mobility and flexibility: Develop programs to help IT companies adapt their business models to changing conditions, in particular by supporting the introduction of remote workflows and the use of cloud technologies.
   - Develop a strategy to overcome skills and regional disparities: This may include retraining programs and incentives for skilled workers to relocate to regions with labor shortages.

Consider the analysis of Ukraine's poultry market, a traditional agricultural sector supported by the country's favorable climate and well-developed grain industry. The poultry market is highly concentrated, with low competition, dominated by just four major producers [16–18]. The market reaches a monopoly threshold given that the three largest enterprises consolidate, a hallmark of an oligopolistic market structure.

The market's external environment analysis reveals that political and economic factors have the most negative impact, primarily due to the ongoing war in Ukraine—the factors largely beyond control. Conversely, technological factors exert the most positive influence on the market's external environment [19, 20]. In response, the government has been proactive in creating opportunities to mitigate the war's adverse effects. Key positive measures include 0% credit support, introduction of

soft loans, government financial aid for agribusiness, and tax holidays. However, the market faces significant barriers, including administrative challenges, environmental concerns, anti-competitive actions by authorities, high capital investment requirements, and intense competition.

Based on the analysis of Ukraine's poultry market, several public policy decisions can be made to support the industry's development and address existing barriers. These decisions may include:

1. Reforming the legislation and regulatory framework, namely
   - Eliminating regulatory gaps that create barriers to the development of the industry. This includes updating and improving the legislation that regulates the activities of poultry enterprises.
   - Completion of land reform, which will ensure stable access to land and reduce the risks associated with the use of agricultural land.
2. Optimization of administrative procedures
   - Simplification and digitalization of the process of obtaining licenses, permits and sanitary and veterinary passports. This may include the creation of an online platform where businesses can apply for and receive the necessary documents, which will reduce bureaucratic obstacles.
3. Financial support and investment
   - Expand financial support programs for agribusiness, in particular through the provision of soft loans and grants. Particular attention should be paid to small and medium-sized enterprises (SMEs) to increase their competitiveness.
   - Stimulating investments in the material and technical base of poultry enterprises to increase production and introduce innovative technologies.
4. Regulation of energy and resource prices
   - Improving state regulation of prices for energy, feed and other material and technical resources used in poultry production. This will help stabilize the costs of enterprises and make their products more competitive.
5. Supporting competition and market development
   - Introduce measures to prevent oligopoly and promote competition in the chicken market. This may include antitrust measures and support for new market entrants.
   - Creating conditions for the development of industrial poultry production, which involves increasing the share of products produced by large enterprises and reducing dependence on private farms.
6. Innovative development of the industry
   - Encouraging the introduction of innovations in the production process, including research development and new technologies in poultry production.

- Support for educational programs for training personnel in the field of agrotechnology and management of agricultural enterprises.

Another example is the analysis of the Ukrainian pharmaceutical market [21], which reveals that investments in research and development are closely tied to capital investments in pharmaceutical production, highlighting the critical role of innovation in driving industry growth. The main market barriers for pharmaceuticals include obtaining permits and licenses, anticompetitive actions of local governments, excessive regulation, lack of effective PPP programs, and price setting. Therefore, measures to reduce these barriers include digitalization of drug registration, mutual recognition of manufacturing certification, acceleration of the approval process of clinical trial protocols, and non-tariff restrictions on imports of goods produced in Ukraine. The strong correlation between GDP and pharmaceutical exports underscores the industry's significant contribution to the national economy (see Table 2). Simultaneously, the negative correlation between population morbidity and indicators such as investment and sales suggests a rising demand for medical products, which places additional pressure on the market.

Based on the above analysis of the Ukrainian pharmaceutical market, the possible decisions that can be made in the public are outlined further on:

1. Support for innovation and research: Given the close link between investment in research and development of production, the government could introduce support programs to encourage innovation. This could include tax incentives for companies investing in R&D, grants for research, and the development of infrastructure for biotechnology and pharmaceutical research.
2. Improving the conditions for attracting investment: The high correlation between GDP and pharmaceutical exports emphasizes the importance of this industry for the country's economy. Taking this into account, decisions can be made

Table 2 Correlation indicators between the main indicators of the pharmaceutical market

Indicator	*Row 1*	*Row 2*	*Row 3*	*Row 4*	*Row 5*	*Row 6*	*Row 7*	*Row 8*	*Row 9*	*Row 10*
Exports	1									
Imports	0.52	1								
Volume of expenditures on innovations	0.25	-0.29	1							
Expenditures on innovations	0.32	0.21	0.13	1						
Expenditures on research and development	0.89	0.36	0.14	0.36	1					
Share of R&D expenditures in GDP	-0.88	0.19	-0.31	0.06	-0.82	1				
Population morbidity, thousand	-0.84	-0.61	0.01	-0.65	-0.89	0.55	1			
Capital investments	0.90	0.40	0.18	0.44	0.99	-0.79	-0.92	1		
Volume of products sold	0.95	0.47	0.23	0.54	0.95	-0.87	-0.94	0.97	1	
GDP	0.92	0.36	0.19	0.38	0.99	-0.90	-0.88	0.98	0.97	1

to create favorable conditions for foreign investors, such as simplifying regulatory requirements, reducing customs barriers, and developing export support programs.

3. Strategic planning in the healthcare sector: The negative correlation between morbidity and investment points to the need for a strategic approach to improving the health care system. The authorities should consider expanding access to medical services and medicines, as well as stimulating domestic production of essential medical goods to reduce dependence on imports.
4. Regulate prices for medical products: Given the growing demand for medical products, consideration should be given to introducing mechanisms for state regulation of prices for key pharmaceutical products. This will help to avoid sharp price increases that may be caused by increased demand.
5. Development of export opportunities: The positive impact of pharmaceutical exports on the economy may warrant the development of a national export development strategy. This may include measures to promote Ukrainian pharmaceutical products on international markets, expand trade relations and reduce barriers to entry to new markets. Such decisions can contribute to the sustainable development of the pharmaceutical industry, improve public health and strengthen the country's economic position.

A sophisticated real-time analytical system known as the Lviv Region Analytical Portal has been launched [22]. This system is designed to analyze regional data and market trends. It encompasses comprehensive information on the social and administrative infrastructure of the region, as well as investment opportunities for investors and donors. Notably, it provides resources for supporting internally displaced persons (IDPs) residing in the Lviv region. The system facilitates the analysis of statistical indicators, which can be presented in various formats, such as tables, graphs, interactive maps, reports, and dashboards. Additionally, it allows for detailed data analysis at various levels, including the entire region, individual districts, communities, and settlements.

Today's global economy increasingly emphasizes innovation as a critical driver of growth. The transition from a factor—and investment-oriented economy to an innovation-oriented economy requires a new approach to market analysis. For the public authorities, this means predicting the impact of technological innovations on traditional markets, exploring the potential of new industries, and stimulating the development of startups. It also implies introducing mechanisms to support research and development (R&D) and investments in digitalization and education to create favorable conditions for innovative economic development. Our society's challenges are enormous, and organizations in the public sphere must be prepared to address them. Particular attention is needed in areas such as climate change, social justice, technology and data science, migration, government capacity, and governance in rural and non-metropolitan regions. At the same time, it is necessary to focus on how these areas interact. For example, climate change has a significant impact on social justice issues, and technology and data science can significantly change the ability of governments to function effectively. We are also seeing a shift in emphasis

in the public sector from a focus on efficiency and effectiveness to a paradigm that emphasizes equity [23–26].

Implementing the EU-Ukraine agreement, particularly the Ukraine Facility, a technical document essential for executing the EU's financial support program for Ukraine will also be a critical undertaking in market analytics. Achieving rapid recovery and fostering long-term economic growth necessitate comprehensive government reforms that will establish the foundation for accelerated economic recovery and enhanced institutional capacity. The Ukraine Facility Plan outlines these reforms to ensure a comprehensive and integrated approach to economic recovery, further development, and Ukraine's integration into the European Union [27].

3 Conclusions and Future Work

In a market economy, the categories of competition and freedom of economic activity are pivotal not only for establishing a market economy but also for enabling society to fulfill its needs effectively. Most markets in a market economy operate under competitive conditions where business entities engage in competitive behavior, influencing resource utilization, cost and price determination, profit generation, and market interaction decisions involving competitors, suppliers, and consumers. Public authorities are responsible for creating conducive conditions for market function and business activities. They aim to encourage competitive behavior among business entities while concurrently fostering an environment that ensures the optimal satisfaction of societal needs, thereby necessitating a significant level of competition. Public authorities are tasked with establishing equitable sectoral state regulations and oversight to maintain the equilibrium between public and private interests while ensuring extensive competition. To achieve this, public authorities may employ various methods for detecting non-competitive behavior, tools to promote the formation and maintenance of significant competition in markets, and criteria to evaluate the impact of regulations on competition. The execution of these tasks mandates a comprehensive analysis of various market components and phenomena, encompassing structural and behavioral indicators. Furthermore, market analysis serves as a fundamental instrument in formulating regional development strategies, aiding public authorities in identifying priority sectors for investment and evaluating potential risks and opportunities. It enables the formulation of effective measures to enhance regional competitiveness, particularly during periods of crisis, allowing regional authorities to adapt their strategies for sustainable economic development and advancing the region's quality of life.

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Machine Learning Approaches for Infectious Disease Surveillance During Emergencies

Dmytro Chumachenko

Abstract This chapter explores the application of machine learning (ML) to infectious disease surveillance during emergencies, such as pandemics, natural disasters, and armed conflicts. It examines the challenges and limitations of data collection in these settings, including data quality, completeness, and integration into existing healthcare infrastructures. The discussion highlights how ML models, utilizing advanced techniques such as data augmentation, feature engineering, and anomaly detection, can significantly improve disease prediction and management accuracy and timeliness. Key points include the potential of ML to revolutionize public health responses through real-time data processing and the integration of diverse data sources. The chapter also addresses the future landscape of ML in public health crises, emphasizing the need for enhanced data collection methods, real-time analytics, and the development of more interpretable and secure ML models. Ultimately, this chapter underscores the transformative potential of ML technologies in improving public health surveillance and response during emergencies while acknowledging the critical need to overcome current challenges to fully realize these benefits.

Keywords Epidemic model · Infectious disease simulation · Machine learning · Emergency · Emergency setting

1 Introduction

Infectious disease surveillance is a critical component of public health that involves the systematic collection, analysis, and interpretation of health data to monitor and prevent the spread of diseases [1]. This process enables health authorities to detect outbreaks early [2], track disease trends [3], and implement timely interventions to control the spread of infections [4]. Surveillance systems rely on various data sources, including clinical reports, laboratory results, and epidemiological data, to provide a

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comprehensive overview of disease activity within a population [5]. By continuously monitoring these data, public health officials can identify emerging threats, assess the impact of interventions, and allocate resources effectively to protect public health.

The importance of infectious disease surveillance is underscored during emergencies, such as natural disasters, conflicts, and pandemics when the risk of disease outbreaks is heightened [6]. In these contexts, traditional surveillance methods may be challenged by disruptions in infrastructure, limited access to healthcare, and population displacement. Despite these challenges, robust surveillance systems are essential for promptly detecting and responding to outbreaks [7]. Enhanced surveillance efforts during emergencies can help mitigate the spread of infectious diseases by facilitating early detection, guiding targeted interventions, and informing public health strategies [8]. Surveillance during emergencies also plays a critical role in allocating limited resources and directing the response efforts of health authorities [9]. Accurate and timely data collected through surveillance systems allow public health officials to identify hotspots of disease activity, prioritize areas for intervention, and deploy resources where they are most needed. This targeted approach ensures that interventions are both efficient and effective, ultimately saving lives and reducing the burden on health systems that are often overwhelmed during emergencies.

Advancements in technology, particularly in data science, artificial intelligence (AI), and machine learning (ML), have significantly enhanced the capabilities of infectious disease surveillance. AI technologies, such as natural language processing and computer vision, facilitate the rapid extraction and interpretation of data from diverse sources, including clinical records, social media, and environmental sensors. This capability allows for real-time monitoring and early detection of disease outbreaks, critical for timely public health responses [10]. AI-driven predictive models can forecast disease spread patterns, providing valuable insights that help health authorities prepare for and mitigate potential outbreaks. Similarly, ML enhances surveillance capabilities by enabling the development of sophisticated models that can identify patterns and anomalies in health data with high accuracy [11]. By analyzing historical and real-time data, ML algorithms detect early signs of disease outbreaks and predict future trends. By continuously learning from new data, ML models can adapt to changing conditions and improve their predictive accuracy, making them indispensable tools in modern infectious disease surveillance systems. These innovations are transforming infectious disease surveillance, making it more adaptive and responsive to the challenges posed by emergencies, and ultimately strengthening public health infrastructures.

This chapter aims to analyze ML approaches for infectious disease surveillance during emergencies.

Current research is a preliminary study of the methodology for assessing the impact of emergencies on the spread of infectious diseases described in [12].

2 Background

Throughout history, infectious disease outbreaks in emergency settings have posed significant challenges to public health systems [13]. Emergencies, such as natural disasters, wars, and humanitarian crises, exacerbate the spread of infectious diseases. The convergence of population displacement, inadequate sanitation, and disrupted healthcare services often leads to rapid and uncontrolled disease transmission. Understanding the historical context of these outbreaks provides valuable insights into the dynamics of disease spread and the importance of robust surveillance systems.

One of the earliest documented infectious disease outbreaks in emergency settings occurred during the Peloponnesian War (431–404 BC), where the crowded and unsanitary conditions within the besieged city of Athens led to a devastating plague [14]. Thucydides, an ancient historian, recorded the high mortality rate and the chaos that ensued, highlighting the outbreak's significant impact on the civilian population and the war effort. This historical account underscores the vulnerability of populations in conflict zones to infectious diseases and the need for effective public health interventions.

In more recent history, the Spanish flu pandemic of 1918–1919, which coincided with the final stages of World War I, serves as a poignant example of how global conflict can exacerbate disease spread [15]. The movement of troops and refugees, combined with overcrowded and unsanitary living conditions, facilitated the rapid transmission of the H1N1 influenza virus. The pandemic resulted in an estimated 50 million deaths worldwide, illustrating the catastrophic impact of infectious diseases in emergency settings. The Spanish flu pandemic also highlighted the limitations of contemporary surveillance and response systems, prompting subsequent advancements in public health infrastructure and disease monitoring.

Natural disasters have similarly been catalysts for infectious disease outbreaks. For instance, the 2010 earthquake in Haiti led to a severe cholera outbreak, affecting hundreds of thousands and resulting in significant loss of life [16]. The destruction of water and sanitation infrastructure, coupled with mass displacement, created ideal conditions for the cholera bacterium to thrive. This outbreak underscored the need for rapid and coordinated public health responses after natural disasters. International aid and enhanced surveillance efforts played pivotal roles in controlling the spread of the disease and providing care to affected populations.

More recently, the Ebola outbreak in West Africa (2014–2016) exemplifies the challenges of infectious disease control in emergency settings [17]. The outbreak began in a rural area but quickly spread to urban centres and across national borders, exacerbated by weak health systems and inadequate surveillance mechanisms. The international response, which included the deployment of medical personnel and the establishment of treatment centres, highlighted the importance of global cooperation and robust surveillance in managing such crises. The Ebola outbreak also underscored the need for community engagement and the integration of local knowledge into public health strategies.

The Russian full-scale invasion of Ukraine in 2022 has further highlighted the devastating impact of wars on public health, particularly in terms of infectious disease outbreaks [18]. The invasion led to massive population displacement, with millions of Ukrainians fleeing their homes and becoming refugees in neighbouring countries or internally displaced persons (IDPs) within Ukraine [19]. This large-scale movement of people, often to crowded and unsanitary conditions, significantly increased the risk of infectious disease outbreaks. The healthcare infrastructure in conflict zones was severely disrupted, with hospitals damaged or destroyed and medical supplies becoming scarce. In these dire circumstances, the surveillance and control of infectious diseases became exceedingly challenging, exacerbating the vulnerability of the affected population to diseases such as COVID-19, tuberculosis, and measles.

The international response to the health crisis in Ukraine underscored the importance of robust surveillance systems and coordinated public health interventions. Humanitarian organizations, alongside the Ukrainian Ministry of Health, implemented emergency measures to monitor and control infectious disease spread [20]. Mobile health units, vaccination campaigns, and the establishment of temporary healthcare facilities played crucial roles in mitigating the impact of the war on public health. The situation in Ukraine also emphasized the need for global solidarity and support in addressing health emergencies in conflict zones. The lessons learned from the ongoing Russian war in Ukraine highlight the critical need for resilient health systems, comprehensive surveillance mechanisms, and international cooperation to protect vulnerable populations during times of conflict and upheaval.

The historical perspective on infectious disease outbreaks in emergency settings reveals recurring themes of vulnerability, the critical role of effective surveillance, and the importance of coordinated public health responses. These historical instances provide valuable lessons for contemporary public health practice, emphasizing the need for preparedness, resilience, and adaptability in emergencies. As global challenges such as climate change and geopolitical conflicts evolve, the lessons learned from past outbreaks will be essential in shaping future public health strategies and interventions.

Traditional disease surveillance methods have long been the cornerstone of public health efforts to monitor and control infectious diseases. These methods typically involve systematically collecting, analyzing, and interpreting health-related data through passive and active surveillance systems [21, 22]. Passive surveillance relies on healthcare providers and laboratories to report cases of diseases to health authorities [23]. This method is cost-effective and relatively simple, utilizing healthcare infrastructure to gather data. However, it often suffers from underreporting and delays in data collection, which can hinder timely response to outbreaks.

Active surveillance, on the other hand, involves proactive data collection by public health officials who seek out cases of diseases through regular contact with healthcare providers and the community [24]. This method is more resource-intensive but provides more accurate and timely data. It is particularly useful for monitoring high-priority diseases and for outbreak investigations. Despite its advantages, active

surveillance can be logistically challenging, especially in resource-limited settings where healthcare infrastructure is weak. Both passive and active surveillance methods rely heavily on laboratory confirmation of cases, which the availability and capacity of laboratory services can limit.

Another traditional disease surveillance method is sentinel surveillance, which involves monitoring a selected group of reporting sites, such as specific hospitals or clinics, to detect trends in disease occurrence [25]. This method provides high-quality data and is useful for monitoring diseases that are difficult to track on a larger scale. However, sentinel surveillance may not capture the full extent of disease spread, particularly in regions not covered by the sentinel sites. Moreover, the representativeness of sentinel sites can be a concern, as the data collected may not accurately reflect the broader population.

Surveillance methods also include syndromic surveillance, which focuses on the early detection of disease outbreaks based on the clinical presentation of symptoms rather than laboratory confirmation [26]. This method can provide early warning signals of potential outbreaks, allowing for quicker public health response. However, syndromic surveillance can produce many false positives, leading to unnecessary alarm and potentially diverting resources from other critical public health activities. Additionally, the lack of specificity in symptom-based data can make it difficult to identify the exact cause of an outbreak without further laboratory investigation.

The limitations of traditional surveillance methods are further compounded in emergency settings, where the disruption of healthcare services, population displacement, and other challenges can severely impact the ability to collect and report accurate data. Delays in data transmission, underreporting, and the logistical difficulties of reaching affected populations can hinder the effectiveness of these surveillance systems. In addition, traditional methods cannot often integrate and analyze volumes of data from diverse sources, limiting their ability to provide a comprehensive and timely picture of disease dynamics.

Integrating technologies and AI in disease surveillance marks a significant advancement in public health, enhancing the accuracy, speed, and scope of monitoring infectious diseases [27]. Traditional surveillance methods, while foundational, often fall short in providing real-time insights and handling the vast amounts of data necessary for effective disease tracking and response. Adopting advanced technologies and AI addresses these shortcomings by offering sophisticated data collection, analysis, and interpretation tools.

AI technologies, such as ML algorithms, natural language processing, and computer vision, have revolutionized how health data is processed and utilized [28]. ML models can analyze vast datasets from diverse sources, including electronic health records, social media, and environmental sensors, to detect patterns and anomalies indicative of potential outbreaks. These models are particularly adept at identifying early warning signals that traditional surveillance methods might miss. For example, ML algorithms can process and interpret real-time data streams to predict disease spread patterns, enabling public health authorities to implement preemptive measures and allocate resources more effectively.

Natural language processing enhances disease surveillance by extracting meaningful information from unstructured data, such as news reports, social media posts, and scientific literature [29]. This capability allows for rapidly identifying emerging health threats and monitoring public sentiment and behaviors related to disease outbreaks. NLP can also automate the surveillance of health-related content across multiple languages and regions, providing a more comprehensive global perspective on disease dynamics. In real-time, computer vision technology can analyze medical images and environmental data to detect and monitor disease vectors, such as mosquitoes.

Mobile technology and geospatial analysis further enhance disease surveillance by providing real-time location-based data [30]. Mobile health applications and wearable devices can track individuals' health metrics and movement patterns, offering valuable data for contact tracing and outbreak containment efforts. Integrated with geographic information systems, geospatial analysis tools enable the visualization of disease spread and the identification of hotspots. This spatial data is crucial for targeting interventions and assessing the impact of public health measures.

While traditional disease surveillance methods have been instrumental in monitoring and controlling infectious diseases, they have significant limitations. Issues such as underreporting, delays in data collection, and logistical challenges in emergency settings can impede timely and effective public health responses. Moreover, the inability to integrate and analyze datasets from various sources restricts the comprehensiveness of these methods. Addressing these limitations requires adopting more advanced surveillance technologies, such as those offered by artificial intelligence and ML, which can enhance disease surveillance efforts' accuracy, timeliness, and scope. Incorporating technologies into disease surveillance represents a transformative shift in public health, providing powerful tools for early detection, real-time monitoring, and predictive analytics. These advancements significantly enhance the ability of health authorities to respond to infectious disease threats promptly and effectively. However, integrating technologies in disease surveillance is not without challenges. Issues related to data privacy, ethical considerations, and the need for robust data governance frameworks must be addressed to ensure the responsible use of these technologies. Moreover, the effectiveness of AI-driven surveillance systems depends on the quality and representativeness of the data they are trained on, necessitating continuous efforts to improve data collection and management practices.

3 Machine Learning Models for Disease Surveillance

Applying ML models for disease surveillance in emergency settings has become increasingly critical in enhancing public health response capabilities. In emergencies, ML models can be categorized into three main tasks: classification, clustering, and forecasting. Classification models are used to identify and categorize disease cases based on various features, aiding in the rapid detection of outbreaks. Clustering

techniques help identify patterns and group similar cases, essential for understanding disease spread and identifying hotspots. Forecasting models predict future disease trends and potential outbreaks, allowing for proactive measures and resource allocation. This section explores the application of these three tasks within ML to improve disease surveillance during emergencies.

3.1 Classification

The paper by Pineda et al. [31] explores the effectiveness of various ML classifiers in identifying influenza cases based on unstructured clinical text data from emergency department reports. The study compares seven ML classifiers, including Naïve Bayes, logistic regression, and random forests, against an expert-constructed Bayesian classifier. The research utilizes 31,268 ED reports from four hospitals, collected between 2008 and 2011, processed using the natural language processing tool Topaz to extract and encode clinical findings. The classifiers' performances are evaluated using the area under the receiver operating characteristic curve (AUC), with results indicating that all ML classifiers significantly outperformed the expert-built Bayesian model. The study also investigates different methods for handling missing clinical information, concluding that marking missing values explicitly improved the performance of most classifiers.

The paper by Bird et al. [32] presents a three-stage ML strategy to classify countries into different risk categories based on COVID-19 data. The study classifies countries into four risk groups for transmission, mortality, and inability to test based on COVID-19 cases, deaths, and testing data per million population. The classification uses geopolitical and demographic data to predict these risks. ML models, including Gradient Boosting, Decision Trees, and Support Vector Machines, were benchmarked using leave-one-country-out cross-validation. The study found that country-level attributes could effectively predict pandemic risks, with the best models achieving high classification accuracy. However, the models performed less effectively on data from later in the pandemic, suggesting that early-stage predictions are more reliable.

Beiser et al. [33] investigate the development and performance of ML models to predict the likelihood of 30-day return hospital admissions for COVID-19 patients discharged from emergency departments (ED). Utilizing data from over 7,500 patients across 116 hospitals in the United States, the study compares four different predictive models: Classification and Regression Tree (CART), Gradient Boosting Machine, Random Forest, and Least Absolute Shrinkage and Selection Operator. The models were evaluated on their ability to predict readmissions based on patient demographics, comorbidities, and clinical features recorded during their ED visits. The study found that ensemble methods performed significantly better than the CART model, with the RF model achieving the highest area under the receiver operating

characteristic curve of 0.75. The study concludes that ML models can effectively identify high-risk patients, thereby aiding in allocating follow-up resources and improving patient outcomes.

The paper by Buvanasri et al. [34] explores open-source intelligence (OSINT) tools for crisis analysis during the COVID-19 pandemic. The study aims to analyze the emotional and mental impact of the pandemic on the public by leveraging data from social media platforms such as Twitter and Facebook. The authors collect a large dataset of social media posts using various OSINT tools and apply sentiment analysis to understand the emotions expressed by individuals during the pandemic. Additionally, the study employs six ML classification algorithms to predict sentiments from the collected data, achieving the highest accuracy with the Multinomial Naive Bayes algorithm. The paper concludes that OSINT and ML can provide valuable insights into public sentiment during crises, offering a more timely and scalable alternative to traditional survey methods.

The paper by Kaur et al. [35] presents a ML-based model for predicting dengue infection positivity, assessing risk levels, and forecasting disease progression in dengue patients. The study proposes a two-tier classification system that first differentiates between dengue-infected and non-infected individuals and then further classifies the severity of the infection into dengue fever (DF), dengue hemorrhagic fever (DHF), and dengue shock syndrome (DSS). Using a dataset of symptomatic and clinical attributes collected from various districts in Punjab, India, over three years, the model leverages the random forest algorithm to achieve high accuracy in predictions. The study demonstrates that including comprehensive data attributes and real-time alerts can significantly enhance the management and treatment of dengue patients, providing a robust framework for early diagnosis and intervention.

Alharbi [36] introduces an innovative approach to healthcare data analysis using a combination of artificial intelligence techniques. The study presents an Artificial Rabbits Optimizer (ARO) integrated with a ML-based healthcare data classification (AROML-HDC) method specifically designed for monitoring and classifying medical data in the EDs of hospitals in Saudi Arabia. The AROML-HDC technique includes min–max normalization, ARO-based feature selection, class-specific cost regulation extreme learning machine (CSCR-ELM) classification, and parameter tuning using the Grasshopper Optimization Algorithm (GOA). The model's performance was tested on benchmark datasets, achieving high classification accuracy and demonstrating its potential to enhance patient tracking, treatment monitoring, and the prediction of patient outcomes.

The study by Lanzilao et al. [37] evaluates the use of ML and statistical classifiers to predict COVID-19 positivity based on routine blood tests and other clinical data collected upon patient admission to the ED. The study involved 971 patients during the first wave of COVID-19. It used various classifiers, including Logistic Regression, Quadratic Discriminant Analysis, Random Forest, Support Vector Machine, Neural Networks, K-nearest neighbor, and Naive Bayes. These classifiers were trained using a combination of laboratory results and clinical features to provide a rapid, cost-effective diagnostic tool to complement RT-PCR testing. The models were tested for internal and external validation, achieving high areas under the ROC curve.

The paper by Campana et al. [38] explores the application of deep learning techniques to detect monkeypox from skin lesion images captured by smartphones. Leveraging transfer learning, the study fine-tunes several convolutional neural network (CNN) models, including MobileNetV3Large, to identify visual features indicative of monkeypox. The models are evaluated using a rigorous tenfold stratified cross-validation approach, focusing on the ability to operate efficiently on mobile devices through model quantization. The paper also incorporates explainable AI (XAI) techniques to validate model predictions, ensuring transparency and reliability in the diagnostic process. The best-performing model, MobileNetV3Large, achieved an F-1 score of 0.928 in binary classification and 0.879 in multi-class classification, demonstrating the feasibility of using mobile-optimized deep learning models for real-time monkeypox detection.

The paper [39] introduces a ML approach using Advanced Recurrent Neural Networks (ARNN) for the early detection of Ebola virus. The study addresses the challenge of imbalanced datasets by implementing strategies to effectively train neural networks. The proposed ARNN model, which incorporates recurrent layers and other mathematical functions, aims to improve prediction accuracy by utilizing comprehensive feature extraction and processing methods. Evaluations demonstrate the model's ability to achieve an average accuracy of 89.86% for predicting Ebola cases, with overall performance reaching 91.63% for all classifications, showcasing its potential in early disease detection (Table 1).

The analysis highlights ML and AI's significant advancements and potential in improving disease surveillance and prediction across various infectious diseases and healthcare contexts, particularly in emergency settings. The studies demonstrate the high accuracy and predictive power of models such as Recurrent Neural Networks (RNN), Convolutional Neural Networks (CNN), and other ML classifiers in detecting diseases like COVID-19, dengue, and Ebola, as well as in analyzing public sentiment during pandemics. These models have shown promise in providing timely and accurate predictions, crucial in emergencies where rapid response is essential. However, limitations and gaps persist, including challenges in handling imbalanced datasets, the need for large and diverse training datasets to improve generalizability, and the complexity of integrating these models into existing healthcare infrastructures, especially in resource-limited and emergency settings. Issues related to data privacy, ethical considerations, and the need for explainable AI to ensure transparency and trust in the model's predictions were consistently noted. These studies underscore the necessity for ongoing research to address these gaps, particularly the refinement of algorithms for better performance in real-world emergency situations and the development of robust data governance frameworks to support the ethical use of AI in public health.

Table 1 Overview of classification models

Authors	Task	Method	Findings
Pineda et al. [31]	To detect influenza cases from emergency department free-text reports, particularly in the presence of missing clinical information	Naïve Bayes (NB), logistic regression (LR), support vector machine (SVM), random forest (RF)	The study found that explicitly marking missing values (not missing at random) generally enhanced the classifiers' performance. The results suggest that ML classifiers, combined with NLP tools like Topaz, hold significant potential for improving the detection of infectious diseases such as influenza from free-text clinical reports in emergency settings
Bird et al. [32]	To classify countries' pandemic risks and preparedness based on demographic and geopolitical data, focusing on the risks of COVID-19 transmission, mortality, and inability to test	SVM, XGBoost, Gradient Boosting (GBM), Bernoulli NB, NB, RF, K-nearest neighbors (KNN), Linear discriminant analysis (LDA), Quadratic discriminant analysis (QDA)	The best models achieved accuracies of 74.51% for transmission risk, 71.24% for mortality risk, and 77.12% for the inability to test. The risk of inability to test should be considered first, as it significantly impacts the accuracy of transmission and mortality risk predictions. The models' effectiveness was higher for early pandemic data, indicating that such approaches are more useful before significant international collaboration changes the data landscape
Beiser et al. [33]	To predict the risk of 30-day return hospital admissions in COVID-19 patients who were discharged from emergency departments	Classification and regression tree (CART), GBM, RF, least absolute shrinkage and selection operator (LASSO)	Common predictive variables across all models included lowest oxygen saturation, temperature, and histories of hypertension, diabetes, hyperlipidemia, and obesity. ML models are feasible and effective tools for identifying COVID-19 patients at high risk of readmission, which can enhance resource allocation and potentially reduce hospital overcrowding during pandemic surges
Buvanasri et al. [34]	To understand and predict public sentiment during the COVID-19 pandemic	RF, NB, multinomial NB	The sentiment analysis showed a fair distribution of positive, neutral, and negative sentiments throughout the pandemic. Among the ML models tested, the MNB algorithm achieved the highest accuracy of 77% in predicting sentiments from social media posts. The study demonstrates the potential of using technological approaches for real-time crisis analysis, providing insights that can help governing authorities in decision-making and resource allocation during pandemics

(continued)

Table 1 (continued)

Authors	Task	Method	Findings
Kaur et al. [35]	To predict dengue infection positivity, estimating the risk levels of infected patients, and forecasting the progression of the disease into more severe forms	RF	Including a wide range of symptomatic and clinical attributes improved the model's predictive capabilities. The system's ability to provide real-time alerts for potential internal hemorrhage and other severe symptoms enhances its utility in clinical settings, enabling timely medical interventions and better managing dengue patients
Alharbi [36]	To improve patient tracking, treatment monitoring, and the accuracy of predicting patient outcomes in EDs	Class-specific cost regulation extreme learning machine (CSCR-ELM)	The study demonstrates the efficacy of combining advanced optimization algorithms with ML techniques to address the challenges of healthcare data analysis in emergency settings, ultimately supporting better clinical decision-making and patient care management
Lanzilao et al. [37]	To predict COVID-19 positivity using blood tests and clinical data collected at the ED, thereby providing an efficient diagnostic tool to support or complement RT-PCR testing	LR, QDA, RF, SVM, KNN, NB	ML models could serve as a valuable bedside tool for early identification of COVID-19 positive patients, potentially guiding further diagnostic efforts and optimizing resource allocation in emergency settings
Campana et al. [38]	To develop and evaluate deep learning models, specifically optimized for mobile devices, to detect monkeypox from skin lesion images captured by smartphones	CNN	The use of explainable AI techniques, such as Grad-CAM, enhances the model's reliability by providing visual explanations for its predictions. The quantization process reduced the model size significantly without a substantial loss in performance, demonstrating the practicality of deploying these models on mobile devices for real-time disease detection
Sharma et al. [39]	To predict early Ebola virus infection using imbalanced datasets and comprehensive feature extraction techniques	ARNN	The model demonstrates robust performance in handling imbalanced datasets and effectively distinguishes between Ebola and other cases

3.2 Clustering

The paper [40] presents an enhanced clustering algorithm to improve emergency call management during the COVID-19 pandemic. The study introduces Heterogeneous DBSCAN (HDBSCAN), an improved version of the traditional DBSCAN algorithm, which accounts for real-world data's dynamic and heterogeneous nature. The HDBSCAN algorithm clusters COVID-19 emergency calls concerning the distribution of hospitals across Saudi Arabia, ensuring an optimal balance between the number of hospitals and emergency calls within each cluster. The algorithm's performance is compared to the original DBSCAN, demonstrating superior results in clustering consistency, reduced outliers, and faster execution times.

The study [41] explores the application of the K-means clustering algorithm to analyze mutations in the SARS-CoV-2 virus. The study utilizes genomic data from the National Center for Biotechnology Information, Kaggle, and GISAID databases to cluster different virus strains and identify mutation patterns. The researchers employed the elbow method to determine the optimal number of clusters, which was found to be five and used Principal Component Analysis (PCA) for dimensionality reduction and visualization of the clustering results. The model's testing included comparisons of sequences from various bat coronaviruses, revealing significant insights into the mutation patterns and their similarities to the original SARS-CoV-2 sequence.

The paper [42] examines the impact of the COVID-19 pandemic on the supply and demand of essential commodities using unsupervised ML techniques. The study utilizes clustering algorithms, specifically K-means, along with rolling mean methods to analyze half-yearly data from 2019 and 2020, assessing variations in the sales of essential goods such as rice, pulses, and oil. By comparing pre-pandemic and post-pandemic data, the authors aim to provide insights to help supply chain industries forecast demand and manage stocks more effectively during crises. The findings indicate significant variations in demand during the pandemic, highlighting the need for adaptive strategies in supply chain management.

The study [43] investigates the use of an unsupervised ML algorithm, specifically a Gaussian Mixture Model, to assess the severity and predict the intubation needs of COVID-19 patients in intensive care units (ICUs). The study utilizes breathing frequency and oxygen saturation signals collected from 279 patients to cluster and predict the likelihood of intubation and length of ICU stay. The research introduces two scores, S24 and MS24, which represent the severity of a patient's condition over 24 h and help categorize patients into three severity levels: green, orange, and red. The study demonstrates the model's accuracy in predicting intubation and its potential to aid in clinical decision-making and resource allocation during the pandemic.

The paper [44] investigates the use of multi-source data and ML techniques to manage public health emergencies, focusing on the COVID-19 pandemic in Beijing. The study combines geographic coordinate data of COVID-19 cases with various socio-economic and environmental factors to create a comprehensive risk assessment model. Utilizing the Multiscale Geographically Weighted Regression

(MGWR) model and a neural network classification model, the research identifies and predicts high-risk areas for COVID-19 transmission within Beijing's Sixth Ring Road. The MGWR model reveals significant spatial heterogeneity in the impact of factors such as population density, road density, and the density of residential and living service facilities on COVID-19 risk. The neural network classification model achieved an accuracy of 85.2%, effectively predicting areas of high epidemic risk, which corresponded well with actual outbreak locations.

The paper [45] presents a novel method to categorize countries into different vulnerability levels based on the impact of COVID-19 on immigrant workers. The study employs a probabilistic likelihood score calculated using Bayes' Theorem. It applies three unsupervised clustering algorithms (K-Means++, Agglomerative Clustering, and BIRCH) to classify countries into five vulnerability labels: Very Low, Low, Medium, High, and Very High. The Young Power in Social Action dataset includes attributes related to migrant workers' demographics, employment, and reasons for returning home during the pandemic. The performance of the clustering algorithms was evaluated using metrics like the Adjusted Rand Index and Mutual Information Score, with BIRCH achieving the highest normalized mutual information score of 0.74.

The paper [46] explores public sentiment regarding the monkeypox outbreak by analyzing Twitter posts. Using unsupervised ML techniques, specifically Bidirectional Encoder Representations from Transformers (BERT) and BERTopic, the study examines tweets from May 6 to July 23, 2022. The analysis identifies three major themes in public discourse: concerns about personal safety, stigmatization of minority communities, and a lack of faith in public institutions. The study highlights significant societal issues, including misinformation, political mistrust, and stigma against LGBTQ+ and racial minority communities, emphasizing the need for sensitive public health communication and policies.

The study [47] investigates the application of various ML algorithms to predict patients' length of stay (LOS) in the ED during the COVID-19 pandemic. The study analyzes data from the Arab Medical Centre Hospital in Jordan, collected over 22 months, to identify critical factors affecting LOS. The research compares the performance of several algorithms, including decision trees, Random Forest, and multilayer perceptron, to categorize LOS into low, medium, and high ranges. The findings demonstrate that the decision stump and REP tree algorithms achieved the highest accuracy, emphasizing the importance of specific features such as patient age, gender, and medical procedures in predicting LOS.

The paper [48] investigates the differences in sentiments expressed by urban and rural populations in the United States regarding COVID-19 topics on Twitter. By analyzing 407 million geotagged tweets collected from May 2020 to January 2022, the study utilizes word embedding models and unsupervised clustering to identify and categorize COVID-19-related topics. Sentiment analysis reveals significant disparities between urban and rural users' views on COVID-19 prevention strategies, vaccination, political figures, and misinformation. The study highlights stronger negative sentiments among rural users towards prevention measures and

notable political polarization in sentiments towards different politicians between the two groups (Table 2).

The findings from the analysis of clustering models underscore the transformative potential of ML and AI in enhancing disease surveillance, predicting patient outcomes, and understanding public sentiment during health emergencies. These studies accurately predicted patient length of stay, classified disease severity, and identified public sentiment disparities, especially in COVID-19 and other pandemics. Limitations and gaps remain, including challenges in handling data heterogeneity, the need for large and diverse datasets to improve model generalizability, and difficulties integrating these advanced models into existing healthcare infrastructure. In emergency settings, crises' unpredictability and rapid evolution further complicate model deployment and effectiveness. The research highlights the importance of continuous refinement of algorithms and the necessity for real-time data to enhance responsiveness and accuracy in emergency health interventions.

3.3 Forecasting

The paper [49] evaluates the effectiveness of 18 different ML algorithms in predicting the need for ICU admission and the mortality of COVID-19 patients. Using data from 10,826 patients from the Mass General Brigham Healthcare system, the study developed models using demographic, clinical, and laboratory data. The study found that ensemble-based models, particularly Random Forest, Gradient Boosting, and Extra Trees, performed the best in predicting ICU admissions and mortality within the first 5 and 28 days of hospital admission, respectively. Important predictive variables included C-reactive protein (CRP), lactate dehydrogenase (LDH), and oxygen saturation for ICU admissions, and eGFR, neutrophil percentage, and lymphocyte percentage for mortality.

Research [50] investigates the application of various supervised ML algorithms to forecast daily patient flow in an ED during the COVID-19 pandemic. The study evaluates five different regression models—Elastic Net, K-Nearest Neighbors, Support Vector Regression, Random Forest, and XGBoost—using the R^2 coefficient of determination to assess their performance. Data were collected from the Sahloul Hospital in Tunisia, covering 12 h daily over a week. The findings highlight the Random Forest model as the most effective, achieving the highest R^2 score, thus proving to be the best model for predicting daily patient inflow and aiding in better ED management.

The paper [51] presents a novel hybrid transfer learning model to predict the animal reservoirs of the COVID-19 virus. The study addresses the challenges of limited annotated virus data and imbalanced host information by combining transfer learning and ensemble learning techniques. The model leverages knowledge from related virus domains to improve prediction reliability for the target virus domain, specifically focusing on COVID-19. The study utilizes genome sequences from GenBank and constructs a benchmark dataset for training and evaluation. The model's

Table 2 Overview of clustering models

Authors	Task	Method	Findings
Houacine et al. [40]	To cluster COVID-19 emergency calls in relation to hospital locations in Saudi Arabia, aiming to optimize ambulance dispatch and emergency response during the pandemic	Heterogeneous DBSCAN	The algorithm efficiently grouped emergency calls with nearby hospitals, optimizing the dispatch of ambulances and enhancing emergency response capabilities. These results highlight HDBSCAN's effectiveness in managing dynamic and heterogeneous data, making it a valuable tool for emergency call management in pandemic situations
Rath et al. [41]	To analyze and cluster mutations in the SARS-CoV-2 virus, aiming to understand the genomic variations and their potential impact on virus transmissibility	K-means	Cluster, which includes Bat Coronavirus HKU and other similar strains, is highly similar to the original SARS-CoV-2 sequence. The study highlights the algorithm's capability to distinguish between various mutation clusters, providing valuable insights for researchers and aiding in understanding virus transmissibility. This approach can serve as a preliminary methodology for predicting future coronavirus transmissibility and assisting in vaccine development
Anitha et al. [42]	To analyze and predict the supply and demand of essential commodities during the COVID-19 pandemic using unsupervised learning methods, specifically focusing on the variations between pre-pandemic and post-pandemic periods	K-means	The K-means clustering algorithm effectively categorized the data into low, average, and high sales clusters, clearly visualizing the demand patterns. These results underscore the importance of using ML models to predict supply and demand, aiding supply chain industries in better managing their resources and ensuring the timely distribution of essential goods during emergencies
Boussen et al. [43]	To predict the intubation needs and severity of COVID-19 patients in ICUs using respiratory signals	Gaussian mixture model	The algorithm, using simple respiratory signals, can efficiently visualize patients' respiratory conditions and assist in decision-making, potentially improving ICU management and patient care during the COVID-19 pandemic

(continued)

Table 2 (continued)

Authors	Task	Method	Findings
Yu et al. [44]	To identify high-risk areas and influencing factors to inform targeted epidemic prevention and control measures	Multiscale Geographically weighted regression	Key influencing factors identified included population structure, road density, residential area density, and living service facility density. The results indicate that areas within the Fifth Ring Road exhibit the highest risk, especially the eastern, southeastern, and southern regions. These findings provide valuable insights for targeted public health interventions and refined governance strategies to manage COVID-19 and similar public health emergencies in urban settings
Bhowmik et al. [45]	To classify countries into different levels of vulnerability based on the impact of COVID-19 on migrant workers, using a combination of probabilistic likelihood scores and unsupervised clustering algorithms	KMeans + +, Agglomerative, BIRCH	The research effectively categorized countries into five vulnerability labels, providing a clear interpretation of the relative safety and stability of migrant workers. The results suggest that combining probabilistic likelihood scores with unsupervised clustering algorithms can reliably identify the vulnerability levels of countries affected by the pandemic, aiding policymakers and migrant workers in making informed decisions
Ng et al. [46]	To analyze public sentiment on the global monkeypox outbreak using unsupervised ML techniques applied to Twitter posts. The goal is to identify key themes and concerns expressed by the public	Bidirectional Encoder Representations from Transformers (BERT)	The public sentiment on Twitter regarding the monkeypox outbreak centres around three major themes: concerns about personal safety, stigmatization of minority communities, and lack of faith in public institutions. Specifically, the analysis reveals widespread fear of the virus, misconceptions about its transmission, stigmatizing views towards LGBTQ + and racial minority communities, and significant political distrust

(continued)

Table 2 (continued)

Authors	Task	Method	Findings
Shbool et al. [47]	To predict the length of stay of patients in the emergency department identifying key predictor variables and categorizing LOS into low, medium, and high ranges	Decision tree (DT), RF, Multilayer perceptron	Key factors influencing LOS include patient demographics, insurance status, mode of arrival, and medical procedures. The research highlights the effectiveness of using ML models to improve resource allocation and management in emergency departments, particularly during the heightened demand caused by the COVID-19 pandemic
Liu et al. [48]	To identify primary COVID-19-related topics on Twitter and compare the sentiments expressed by urban and rural users in the United States towards these topics using word embedding and unsupervised learning techniques	SentiWordNet	Rural users expressed stronger negative sentiments towards COVID-19 prevention strategies and vaccinations than urban users. There was a significant political divide, with rural users exhibiting stronger negative sentiments towards Democratic politicians, while urban users were more critical of Republican politicians. These findings demonstrate the utility of social media analysis in understanding public sentiment and guiding geographically targeted public health interventions

performance is validated through simulations on UCI benchmarks and viral genome datasets, demonstrating superior accuracy compared to traditional methods.

The study [52] presents a computational framework that leverages large-scale ML within an artificial society to predict and analyze the Ebola Virus Disease (EVD) spread in Beijing. The study constructs an artificial Beijing based on geodemographic data and integrates ML to optimize individual behaviours and interactions. The Ebola course and propagation models are established using parameters from the West African Ebola outbreak. The study simulates different scenarios of EVD spread and evaluates various emergency response interventions. The results indicate that, with appropriate interventions, a large-scale Ebola outbreak in Beijing can be effectively prevented.

The paper [53] uses ML techniques to investigate the factors influencing evacuation rates during Hurricane Laura. The study utilizes a diverse dataset that includes cellular phone-based mobility data, Twitter data, census data, geographical information, COVID-19 case rates, and the CDC's Social Vulnerability Index. The researchers apply a Random Forest algorithm to predict evacuation rates across census tracts in Louisiana and Texas, achieving a mean absolute percent error of 4.9%.

Key predictors include previous evacuation behaviour, rainfall forecasts, COVID-19 case rates, and Twitter activity. The study highlights the significant role of social vulnerability, with higher vulnerability consistently correlating with lower evacuation rates, thus offering insights into improving evacuation planning and preparedness in future emergencies.

The paper by Zhou and Li [54] presents a comprehensive approach to predicting COVID-19 vaccine uptake using both traditional clinical data and innovative infodemiological data. The study combines autoregressive integrated moving average (ARIMA) models with ML methods, including linear regression with ordinary least squares (OLS), most minor absolute shrinkage and selection operator (LASSO), and ensemble methods like boosting and random forest. By incorporating web search queries related to COVID-19 vaccinations, the research aims to enhance the accuracy of vaccine uptake forecasts. The study finds that stacking regression models using both clinical and web data significantly improves prediction accuracy, which can assist policymakers in optimizing vaccine distribution and addressing vaccine hesitancy.

The paper [55] examines the effectiveness of different time-series forecasting models for predicting key performance indicators in EDs during the COVID-19 pandemic. The study compares the ARIMA, Prophet, and General Regression Neural Network (GRNN) models using data from a UK hospital's ED. These KPIs include the number of patients in the department, patient attendances, unallocated patients with a decision to admit, and medically fit for discharge. The research highlights that GRNN outperforms the other models, particularly during periods of sudden change such as the COVID-19 lockdown, demonstrating higher accuracy and reliability in predicting patient flows and aiding in resource management.

The paper [56] presents a study on developing and evaluating an ML-based system to predict COVID-19 cases and mortality rates. The researchers employed various time series models, including PROPHET, Autoregressive (AR), ARIMA, and Long Short-Term Memory (LSTM), to forecast the spread of COVID-19 based on country-wise data of confirmed, detected, recovered, and death cases. The study found that PROPHET and AR models outperformed the others, demonstrating low prediction error rates. This proposed system aims to assist health departments, especially in underdeveloped countries, by providing timely predictions to help manage healthcare resources and prevent the spread of the virus.

The paper [57] presents an innovative framework for predicting the risk of waterborne diseases, such as cholera, in post-disaster environments using high-resolution earth observation data and ML techniques. Focusing on the aftermath of Hurricane Matthew in Haiti, the study develops multiple models to identify significant environmental and social variables contributing to cholera outbreaks. These models integrate data on precipitation, temperature anomalies, population density, and hurricane-induced damage. The research demonstrates that incorporating high-resolution data and ML can enhance the accuracy of cholera risk predictions, providing valuable insights for humanitarian aid and disease management (Table 3).

The analysis of forecasting ML models highlights the significant advancements in ML and AI for enhancing disease surveillance, patient management, and public

Table 3 Overview of forecasting models

Authors	Task	Method	Findings
Subudhi et al. [49]	To identify which are the most effective in predicting ICU admission and mortality among COVID-19 patients, using various demographic, clinical, and laboratory data	AdaBoost, Bagging, Gradient Boosting (GB),. RF, XGBoost, LR, Passive aggressive classifier, GaussianNB, KNN, SVM, DT, QDA	Key predictive factors for ICU admissions included CRP, LDH, and oxygen saturation, while for mortality, the significant variables were eGFR, neutrophil percentage, and lymphocyte percentage. Despite the overall success, the study noted a decrease in model performance when applied to a temporally distinct validation cohort, indicating the need for continuous model updates and adjustments in the face of evolving pandemic dynamics
Hamzaoui, et al. [50]	To forecast daily patient flow in an emergency department during the COVID-19 pandemic	Elastic Net, KNN, SVM, RF, XGBoost	Key performance metrics show that Random Forest provides the best balance of accuracy and computational efficiency. The study underscores the potential of ML models to optimize patient management in emergency settings by predicting patient inflow, reducing waiting times, and improving the overall efficiency of emergency departments
Ye et al. [51]	To predict the reservoir hosts of newly discovered viruses, including COVID-19, by utilizing related virus domain information to overcome data scarcity and class imbalance issues	SVM, XGBoost, AdaBoost	The model achieved high accuracy and reliability by integrating transfer learning to reduce distribution variance and ensemble learning to address class imbalance. The results indicated that the most probable reservoir hosts for COVID-19 are species of bats, specifically Petrobat, with high confidence levels
Zhang et al. [52]	To predict and analyze the spread of Ebola in Beijing, and to assess the effectiveness of various emergency response interventions	Hybrid	The propagation model showed that without interventions, a significant outbreak could occur. However, simulations of different emergency response levels demonstrated that rigorous interventions, such as timely isolation, vaccination, and disinfection, could effectively control the spread of the virus. The findings suggest that such a computational approach is valuable for planning and executing emergency responses to infectious disease outbreaks in urban settings

(continued)

Table 3 (continued)

Authors	Task	Method	Findings
Brower et al. [53]	To predict evacuation rates during Hurricane Laura using a combination of weather forecasts, social media data, COVID-19 case rates, and other socio-demographic and geographic factors	RF	The model effectively predicts evacuation rates, with key predictors being previous evacuation behaviour, rainfall forecasts, COVID-19 case rates, and Twitter data. Higher social vulnerability is consistently associated with lower evacuation rates. The findings suggest that integrating diverse data sources, including social media and public health metrics, can enhance the accuracy of evacuation predictions and inform more effective emergency response strategies
Zhou and Li [54]	To develop and evaluate a hybrid forecasting model that combines clinical data with infodemiological data from web searches to predict COVID-19 vaccine uptake rates in the US	ARIMA	Key predictors from web data include search queries related to vaccine side effects, availability, and public perceptions. The study demonstrates that incorporating real-time infodemiological data can enhance the accuracy of vaccine uptake forecasts, providing valuable insights for public health strategies to increase vaccination rates and manage vaccine distribution effectively
Duarte et al. [55]	To improve resource allocation and management of EDs during the COVID-19 pandemic	ARIMA, Prophet, GRNN	The research concludes that ML models like GRNN can significantly enhance the prediction of patient flows in EDs, thus supporting better decision-making and resource management in healthcare settings, particularly during emergency situations
Hussain et al. [56]	To predict the weekly confirmed COVID-19 cases and potential deaths and to propose a COVID-19 warning system based on these predictions	Prophet, AR, ARIMA, LSTM	The models were able to predict the number of confirmed cases and deaths effectively, demonstrating their potential utility in a COVID-19 warning system. The findings indicate that such a system could be valuable for healthcare departments to monitor and manage the pandemic, especially in regions with limited healthcare infrastructure. The research also highlighted the correlation between population size and the number of COVID-19 cases and deaths, emphasizing the importance of including demographic data in predictive models
Nusrat et al. [57]	To forecast the risk of cholera outbreaks in post-disaster settings, specifically following Hurricane Matthew in Haiti	Weighted sum model	The study finds that models incorporating high-resolution environmental and social data significantly improve cholera risk predictions. Among the models tested, those using enhanced variables such as cloud height, wind speed, and building damage data performed better in identifying high-risk areas

health responses during emergencies. These studies showcase the efficacy of various models in predicting outcomes such as ICU admissions, patient flows, COVID-19 vaccine uptake, and disease outbreaks. The application of these technologies spans diverse scenarios, including emergency departments, post-disaster settings, and pandemic monitoring, demonstrating their broad utility. Limitations and gaps persist, including challenges with data heterogeneity, the need for large and diverse datasets for robust model training, and difficulties in integrating these systems into existing healthcare frameworks. The rapidly evolving nature of emergencies often outpaces model updates, reducing predictive accuracy over time.

3.4 Other Tasks

The paper [58] explores the application of data augmentation techniques to improve the accuracy and efficiency of ML and deep learning models in detecting COVID-19 from medical images. The study addresses the challenge of limited and unreliable data by employing two data augmentation strategies: simple image transformations and Generative Adversarial Networks (GANs). The researchers developed two models, CNN and ConvLSTM, and tested their performance on augmented datasets of X-ray and CT images. The results demonstrated significant improvements in detection accuracy, logarithmic loss, and testing time with data augmentation, reporting an average increase in COVID-19 detection accuracy between 4 and 11%.

The paper [59] discusses the development of a concise CNN model for real-time COVID-19 diagnosis using X-ray images. The study addresses the need for efficient and deployable diagnostic tools on mobile and edge devices with limited processing capabilities. The proposed model employs image enhancement, data augmentation, and hyperparameter tuning to improve diagnostic accuracy. The experimental results demonstrate that the model achieved a 98% accuracy rate, outperforming popular transfer learning models like Xception, ResNet50, and Inception.

The paper [60] addresses the challenge of performance degradation in decentralized ML frameworks, specifically Swarm Learning (SL), due to non-independent and identically distributed (non-IID) data. The study proposes a novel framework called DP-SL-GAN, which combines generative adversarial networks (GANs) with differential privacy to augment non-IID data, making it more homogeneous across different participants. This approach ensures data privacy while improving the model's performance on non-IID datasets. The framework is validated using three real-world clinical datasets: Tuberculosis, Leukemia, and COVID-19, demonstrating superior performance compared to state-of-the-art methods.

The paper by Rasheed and Shubair [61] explores an advanced ML framework for diagnosing COVID-19 from chest X-ray images. The study integrates transfer learning (TL) networks—AlexNet, ResNet101, and SqueezeNet—with various feature-selection techniques such as iterative neighbourhood component analysis (iNCA), iterative chi-square (iChi2), and iterative maximum relevance-minimum redundancy (MMR). The framework is designed to accurately classify COVID-19,

pneumonia, and normal cases by enhancing image data through stationary wavelet transformation and data augmentation techniques. The proposed model achieved an impressive classification accuracy of 99.24% using the combination of AlexNet, ResNet101, SqueezeNet, iChi2, and support vector machine (SVM).

The paper [62] proposes a hybrid approach to classify COVID-19 and non-COVID-19 cough samples using feature engineering and deep learning models. The study utilizes an SVM classifier based on a high-dimensional space of acoustic features and a CNN trained on log-mel spectrograms of cough sounds. Combining these two models by fusing their probability scores resulted in a significant improvement in classification performance, achieving an AUC of 0.81 on the DiCOVA-2021 challenge blind test dataset, a 10.9% improvement over the baseline. The research also includes an analysis of the explainability of the CNN model, providing insights into which parts of the cough signal most indicate COVID-19.

The paper [63] presents a novel framework that integrates multi-modality data to predict the severity of COVID-19 inpatients. This framework leverages both electronic medical records (EMR) and chest CT images, employing a High-order Factorization Network (HoFN) to capture complex interactions among clinical features without extensive feature engineering. Additionally, an attention-based deep CNN is used to process lung CT images, and a loss function is designed to align features from both modalities into a shared feature space, enhancing the model's robustness against missing data. Experimental results on a real-world dataset demonstrate the model's superior performance and robustness, significantly improving the accuracy of COVID-19 severity prediction.

The study [64] proposes a novel Large Deviations Anomaly Detection (LAD) algorithm for identifying anomalies in large, high-dimensional datasets, specifically focusing on multivariate time series data. This study is motivated by the need for effective anomaly detection in public health scenarios, such as monitoring COVID-19 cases and mortality rates across various regions. The LAD algorithm leverages large deviations theory to compute anomaly scores without the need for dimensionality reduction or feature selection, making it scalable and efficient for high-dimensional data. The paper includes a comprehensive empirical analysis using real-world COVID-19 data from U.S. counties, demonstrating the algorithm's ability to detect regions with significant deviations in COVID-19 trends.

The paper [65] proposes a deep learning-based anomaly detection framework for passive COVID-19 detection using cough and breath audio samples. The study utilizes public, crowdsourced datasets from MIT and IISC Coswara, focusing on overcoming the challenges posed by the extreme imbalance in the available data, with only 4% of samples being COVID-19 positive. The authors investigate deep anomaly detection methods, including convolutional and variational autoencoders, combined with traditional anomaly detectors like One-Class SVM, Local Outlier Factor, and Elliptic Envelope. The best-performing model, a variational autoencoder with an elliptic envelope, achieved an AUC of 0.65.

The paper [66] proposes a hybrid deep learning framework to detect anomalies in multivariate spatio-temporal data for early identification of COVID-19 outbreaks. This framework uses autoencoders to reconstruct the data and identify anomalies

based on the reconstruction error, thereby handling both spatial and temporal dependencies in the dataset. The framework is validated using COVID-19 data from various Italian regions. It effectively detects early signs of outbreaks in central and southern Italy by leveraging the outbreak patterns learned from northern Italy.

Other approaches include data augmentation, feature selection and anomaly detection and collectively underscore the transformative potential of ML and deep learning techniques in enhancing disease detection, prediction, and management, particularly in emergency settings such as the COVID-19 pandemic (Table 4). These studies highlight significant advancements, including improved diagnostic accuracy through hybrid models, effective anomaly detection using autoencoders, and enhanced severity prediction via multi-modality data integration. However, notable limitations and gaps remain, such as the need for larger, high-quality datasets to improve model robustness and generalizability and challenges in integrating these advanced models into existing healthcare infrastructures.

4 Leveraging Data

Data collection in emergency settings, such as during natural disasters, pandemics, or armed conflicts, poses unique challenges and requires robust methodologies to ensure the timely and accurate information gathering. These settings often involve rapidly changing environments, disrupted infrastructures, and urgent needs for immediate decision-making. This subsection discusses various methods for data collection in such contexts, emphasizing their applicability, advantages, and limitations.

Surveillance systems are foundational in collecting data during emergencies [67]. These systems involve structured data collection from healthcare facilities, laboratories, and other relevant institutions. Traditional surveillance methods include routine reporting by hospitals and clinics, which provide critical data on disease incidence, mortality rates, and other health indicators. Enhanced surveillance, a more proactive approach, may involve active case finding and intensified reporting to rapidly capture a broader scope of data [68].

Surveillance systems have advantages, including the systematic and continuous collection of data, which facilitates trend analysis and early detection of outbreaks. However, their effectiveness can be compromised by disrupting healthcare services and infrastructure during emergencies. Additionally, these systems often rely on timely and accurate reporting, which can be hindered by overwhelmed healthcare facilities and staff shortages.

Mobile technology has revolutionized data collection in emergency settings [69]. Mobile phones and tablets equipped with specialized applications can be used to collect data in real time. These devices can capture a wide range of data types, including text, images, geolocation, and even audiovisual recordings. Mobile data collection platforms, such as Open Data Kit (ODK) [70] and CommCare [71], provide customizable forms that can be used to gather data efficiently and accurately.

Table 4 Overview of other ML models

Authors	Task	Method	Findings
Sedik et al. [58]	Data augmentation. To develop and evaluate the effectiveness of data-augmented ML and deep learning models in enhancing the accuracy of COVID-19 detection from medical images, addressing the limitations posed by insufficient and unreliable data	CNN	The augmented datasets led to an average increase in detection accuracy between 4 and 11% compared to non-augmented models. This approach provides a reliable and efficient method for COVID-19 detection, potentially aiding clinicians in making more accurate diagnoses and improving patient outcomes. Integrating data augmentation techniques into ML and deep learning frameworks proves crucial for enhancing model learnability and effectiveness, especially in scenarios with limited data availability
Kaur et al. [59]	Data augmentation. To detect COVID-19 from X-ray images, optimized for deployment on devices with limited processing resources	CNN	Key enhancements included using Gaussian blur for image preprocessing and optimized hyperparameters, reducing overfitting and increasing the model's generalizability. The research underscores the model's potential for real-time application on mobile and edge devices, providing a rapid and reliable diagnostic tool for COVID-19
He et al. [60]	Data augmentation. To address the non-IID problem in decentralized clinical ML, enhancing model performance while preserving data privacy	GAN	The proposed framework significantly improves model accuracy across three clinical datasets (Tuberculosis, Leukemia, and COVID-19), proving the efficacy of using GANs for data augmentation in decentralized settings. Additionally, the integration of differential privacy ensures that the data privacy of participants is maintained throughout the process
Rasheed and Shubair [61]	Feature engineering. To develop and evaluate a robust ML-based diagnostic tool that uses enhanced feature generation and selection techniques to accurately classify COVID-19, pneumonia, and normal cases from chest X-ray images	CNN, LDA, SVM	The study finds that integrating TL networks with iterative feature-selection techniques significantly improves classification performance. Specifically, the combination of AlexNet, ResNet101, SqueezeNet, iChi2, and SVM achieved a classification accuracy of 99.24%

(continued)

Table 4 (continued)

Authors	Task	Method	Findings
Avila et al. [62]	Feature engineering. To develop and evaluate a hybrid ML framework that combines feature engineering and deep learning techniques for classifying COVID-19 from cough sounds	SVM	The feature selection process highlighted the importance of specific acoustic features, while the explainability analysis of the CNN model using Score-CAM revealed that the model primarily focuses on the second phase of the cough, which aligns with known differences between COVID-19 and other types of coughs
Zhou et al. [63]	Feature engineering. To develop and evaluate a multi-modality feature learning and fusion model that integrates EMR and chest CT images to accurately predict the severity of COVID-19 inpatients	CNN	The HoFN effectively captures high-order feature interactions, while the attention-based CNN focuses on critical lung regions in CT images. Using a custom loss function to align multi-modality features enhances the model's robustness
Guggilam et al. [64]	Anomaly detection. To develop and validate the LAD algorithm for scalable and efficient anomaly detection in large collections of multivariate time series data, focusing on identifying anomalous trends in COVID-19 case and mortality data	Large deviations anomaly detection	The model's ability to handle high-dimensional data without additional preprocessing steps, such as dimensionality reduction, proves advantageous in real-time applications. The study also highlights the robustness and scalability of the LAD algorithm, making it suitable for large-scale public health monitoring and other domains requiring real-time anomaly detection in high-dimensional time series data
Murthy and Agu [65]	Anomaly detection. To develop and evaluate deep learning-based anomaly detection models for the passive detection of COVID-19 using audio data	Deep anomaly detector	The research highlights that deep anomaly detection methods can effectively handle imbalanced datasets and suggests that these models can passively detect COVID-19 from audio data. However, the paper also notes limitations, such as the need for more COVID-positive audio samples and the variability introduced by different phone models and recording environments

(continued)

Table 4 (continued)

Authors	Task	Method	Findings
Karadayi et al. [66]	Anomaly detection. To develop and evaluate an unsupervised anomaly detection framework that utilizes deep learning to detect early COVID-19 outbreaks in multivariate spatiotemporal data	ARIMA, CNN, LSTM	The framework outperforms state-of-the-art anomaly detection methods in data-scarce and high contamination scenarios, showcasing its robustness and generalization capabilities. The study highlights the utility of incorporating spatial neighbourhood data and using a hybrid approach to enhance anomaly detection performance, providing timely insights critical for public health decision-making during pandemics

Mobile data collection offers several advantages, including gathering data quickly and directly from the field, even in remote or inaccessible areas. The real-time data transmission capabilities enhance the immediacy of information, allowing for swift response actions. However, challenges include ensuring the availability of devices, maintaining battery life, and securing reliable internet connectivity. Moreover, data privacy and security concerns must be addressed, particularly in conflict zones or politically sensitive areas.

Remote sensing technologies, such as satellite imagery and aerial drones, provide invaluable data in emergency settings [72]. These technologies can monitor large areas and capture data on environmental changes, population movements, and infrastructure damage. GIS integrate spatial data from remote sensing with other data sources to create comprehensive maps and models that support decision-making.

Remote sensing and GIS offer the advantage of extensive spatial coverage, which is crucial for assessing the impact of disasters and planning interventions. They can operate independently of ground conditions, particularly in inaccessible areas. However, interpreting remote sensing data requires specialized expertise and can be resource-intensive. Additionally, there may be delays in acquiring and processing satellite imagery, which can impact the timeliness of data.

Crowdsourcing leverages the collective effort of many people to gather data, often through digital platforms [73]. In emergencies, affected populations and volunteers can report observations, needs, and conditions using social media, mobile apps, and dedicated websites. Participatory data collection involves engaging community members in the data collection process, which can enhance the quality and relevance of the data collected.

Crowdsourcing and participatory methods can rapidly gather large volumes of data and engage the community in the response process. These methods can provide real-time insights and fill gaps left by traditional data collection systems. However, they also present challenges, such as ensuring data accuracy and managing the influx of unverified information. Data quality control mechanisms and source verification are critical to crowdsourced data's reliability.

Social media platforms, such as Twitter, Facebook, and Instagram, are increasingly recognized as valuable real-time data sources in emergencies [74]. Social media data can provide insights into public sentiment, the spread of misinformation, and the on-the-ground impact of disasters [75]. OSINT involves collecting and analyzing publicly available information from various online sources to gain situational awareness [76].

Social media and OSINT offer the advantage of immediate access to a vast amount of real-time data. These sources can complement traditional data collection methods and provide a broader perspective on the emergency. However, the data obtained from social media and OSINT can be noisy and unstructured, requiring sophisticated analytical tools and techniques to extract meaningful information. Additionally, issues related to data privacy and the ethical use of publicly available information must be carefully managed.

Traditional data collection methods, such as surveys and interviews, remain essential in emergency settings [77]. These methods involve structured or semi-structured interactions with affected individuals, healthcare providers, and other stakeholders to gather detailed information on health status, needs, and perceptions. Surveys can be conducted in person, by phone, or online, while interviews may be individual or focus-group-based.

Surveys and interviews provide in-depth qualitative and quantitative data, offering valuable insights that other methods may not capture. They allow for the collection of specific information tailored to the emergency response needs. However, these methods can be time-consuming and resource-intensive, particularly in large-scale emergencies. The accuracy of the data may also be influenced by respondent bias and the interviewer's skill.

Effective data collection in emergency settings requires a multi-faceted approach combining traditional methods and innovative technologies. Each method has its strengths and limitations, and their integration can enhance the comprehensiveness and reliability of the data collected. The specific context of the emergency should guide the choice of data collection methods, the type of data needed, and the available resources. Ensuring data quality, addressing privacy concerns, and adapting to the rapidly changing conditions of emergencies are critical to the success of data collection efforts.

Data quality and availability are critical to effective data collection and analysis, particularly in emergencies. Ensuring data accuracy, reliability, and comprehensiveness is essential for informed decision-making and timely interventions. However, numerous challenges arise in maintaining high data quality and availability during emergencies, where conditions are often chaotic, and resources may be limited.

One of the primary challenges in data quality during emergencies is the accuracy and completeness of data. In crises, data is often collected rapidly from various sources, including healthcare facilities, mobile applications, remote sensing technologies, and social media platforms. The haste and diversity of sources can lead to inconsistencies and errors. For instance, healthcare providers may be overwhelmed, leading to incomplete patient records or misreported information. Similarly, data

collected through crowdsourcing or social media may be unreliable due to the potential for misinformation or biased reporting. Ensuring accuracy requires stringent data validation and verification processes, which can be difficult to implement swiftly in emergencies.

Another significant challenge is the timeliness and relevance of data. In emergencies, the situation can evolve rapidly, and data that is accurate today may become outdated tomorrow. This dynamic nature of emergencies necessitates real-time data collection and processing, which can be technologically and logistically challenging. Delays in data transmission, processing bottlenecks, and the need for real-time analytics infrastructure can hinder the prompt availability of relevant data. Additionally, integrating data from multiple sources to provide a comprehensive picture requires efficient data management systems, which may not be readily available in all settings.

Infrastructural and logistical issues also hamper data availability. In many emergencies, especially natural disasters or conflicts, physical infrastructure such as telecommunications networks, power supplies, and transportation routes may be damaged or destroyed. This can severely limit the ability to collect and transmit data from affected areas. Reliance on alternative data collection methods, such as satellite imagery or mobile data collection tools, becomes essential in such situations. However, these methods also have limitations, including the need for specialized equipment and expertise.

Privacy and security concerns further complicate data quality and availability. The collection and dissemination of data in emergencies often involve sensitive information, including personal health records and location data. Ensuring the confidentiality and security of this information is paramount to protect individuals' privacy and prevent misuse. However, implementing robust data security measures can be challenging in the fast-paced environment of an emergency response. There is a risk that data breaches or unauthorized access could occur, undermining public trust and potentially leading to harmful consequences.

Data interoperability is another critical challenge. Emergency data is typically collected from various sources, each with its format, standards, and protocols. Integrating these disparate data sets into a cohesive and usable form requires significant effort in standardization and harmonization. The lack of interoperability can lead to fragmented data, making it difficult to understand the situation comprehensively and accurately. Developing common data standards and ensuring that different systems communicate effectively are essential to overcoming this challenge.

Human factors play a significant role in data quality and availability. The individuals involved in data collection, entry, and analysis must be adequately trained and equipped to handle the specific challenges of emergency data. Inadequate training or familiarity with data collection tools can lead to errors and inconsistencies. Moreover, the high-stress environment of an emergency can affect the performance and accuracy of those involved in data management tasks.

Missing data is an inevitable challenge in any data collection process, especially in emergency settings, and can significantly impair the quality and reliability of the dataset. The presence of missing data can lead to biased results, reduced statistical

power, and compromised validity of the analysis. Therefore, effectively handling missing data and employing appropriate imputation methods are crucial steps to ensure the robustness of any data-driven conclusions.

Missing data in emergency settings can arise from various sources. In healthcare data, for example, missing values may result from incomplete patient records, errors in data entry, or record loss due to infrastructure damage [78]. In survey data, non-response or partial responses can lead to gaps. Additionally, real-time data streams from mobile devices or remote sensing technologies might suffer from transmission losses or technical failures [79]. Recognizing the types and sources of missing data is the first step in addressing this issue.

The nature of missing data can be categorized into three main types: Missing Completely at Random (MCAR), Missing at Random (MAR), and Missing Not at Random (MNAR). MCAR occurs when the missingness is independent of both observed and unobserved data, making it the least problematic type. MAR occurs when the missingness is related to observed data but not the unobserved data. MNAR is the most challenging, as the missingness is related to the unobserved data, which can introduce significant biases. Understanding these distinctions is essential for selecting appropriate imputation methods.

One common approach to handling missing data is listwise deletion, where any record with missing values is excluded from the analysis. While this method is simple to implement, it can lead to a substantial data loss, particularly if the missingness is extensive, and may result in biased estimates if the data is not MCAR. Pairwise deletion, another method, only excludes missing data on a case-by-case basis for each analysis, preserving more data but complicating the interpretation of results.

Imputation methods offer more sophisticated approaches to handling missing data. Simple imputation techniques include mean, median, or mode imputation, where missing values are replaced with the central tendency measure of the observed data. Although easy to implement, these methods can reduce variability in the data and potentially introduce bias if the data is not MCAR.

More advanced imputation techniques involve predictive models. Regression imputation uses observed data to predict missing values through regression models. For instance, if demographic data is missing in a health dataset, other variables like age, gender, or geographic location can be used to predict and fill in the missing entries. While more accurate than simple imputation, regression imputation assumes a linear relationship between variables, which may not always hold.

Multiple imputation is a robust method that accounts for the uncertainty of missing data by creating several plausible datasets and combining the results from each. This approach involves three steps: imputation, analysis, and pooling. Multiple imputation provides more reliable estimates than single imputation methods and is particularly useful when dealing with MAR data. However, it can be computationally intensive and requires specialized statistical software.

ML algorithms offer another powerful set of tools for imputation. Techniques such as KNN, random forests, and neural networks can be employed to predict missing values based on complex patterns in the data. KNN imputes missing values by averaging the values of the nearest neighbours in the dataset, while random forests use

an ensemble of decision trees to predict missing entries [80]. Neural networks, with their ability to model nonlinear relationships, can provide highly accurate imputations but require large datasets and significant computational resources.

In emergency settings, where timely data analysis is crucial, the imputation method must balance accuracy with computational efficiency. Automated and scalable imputation methods, such as ML ones, are particularly advantageous. These methods can handle large datasets and adapt to the evolving nature of the data as the emergency unfolds.

Handling missing data and employing appropriate imputation methods are essential for maintaining the integrity and reliability of datasets in emergency settings. Understanding the nature of missing data and selecting suitable imputation techniques can mitigate biases, preserve the dataset's usability, and enhance the validity of data-driven decisions. As data collection continues to evolve, particularly in high-stakes emergency contexts, ongoing research and development of more efficient and accurate imputation methods will remain a critical area of focus.

Maintaining high data quality and availability in emergency settings is fraught with challenges that span accuracy, timeliness, infrastructure, privacy, interoperability, and human factors. Addressing these challenges requires a multi-faceted approach that includes robust data validation processes, real-time data analytics capabilities, secure data management systems, and comprehensive training programs for personnel. By overcoming these obstacles, emergency response efforts can be significantly enhanced, leading to more effective and timely interventions.

5 Discussion and Conclusions

The studies reviewed in this chapter highlight the potential of ML and AI to revolutionize infectious disease surveillance, particularly during emergencies. These technologies offer significant data collection, analysis, and prediction advancements, enabling more timely and accurate public health responses. ML models have demonstrated high accuracy in predicting disease outbreaks, classifying disease severity, and identifying public sentiment during health crises. Techniques such as data augmentation, feature engineering, and anomaly detection have shown promise in improving model performance and handling the complexities of emergency data.

Integrating multiple data sources, including electronic health records, remote sensing data, and social media, enhances the comprehensiveness of surveillance efforts. ML models' ability to process and analyze large volumes of diverse data in real time provides critical insights that can inform public health interventions and resource allocation. Despite these advancements, the effective deployment of ML models in emergency settings is hindered by data quality issues, infrastructural limitations, and the need for continuous model adaptation.

While promising, ML approaches for infectious disease surveillance during emergencies face several significant limitations and challenges. One primary limitation is the quality and completeness of data. In emergency settings, data collection is

often rapid and fragmented, leading to missing values, inconsistent data formats, and reporting delays. These data quality issues can severely impact the performance and reliability of ML models, which rely on high-quality, comprehensive datasets to make accurate predictions. Furthermore, data obtained during emergencies might be biased or incomplete due to overwhelmed healthcare systems and logistical constraints, making it difficult to develop robust models.

Another challenge is integrating ML models into existing healthcare infrastructures. Many healthcare systems, particularly in low-resource settings, lack the technological infrastructure and skilled personnel to implement and maintain advanced ML models. The complexity of these models requires specialized knowledge and continuous monitoring, which can be challenging to sustain during crises. Additionally, deploying ML models must consider ethical and legal implications concerning data privacy and security. Ensuring the confidentiality of sensitive health information while utilizing large-scale datasets for ML purposes remains a critical concern.

The dynamic and rapidly changing nature of emergencies poses a significant challenge for ML models. These models often require frequent updates and retraining to remain relevant and accurate, but the fast-paced environment of emergencies can hinder this process. The models must adapt to new patterns and anomalies as they arise, which requires a continuous influx of real-time data and sophisticated update mechanisms. The unpredictability of emergencies, such as natural disasters or pandemics, further complicates the model's ability to provide consistent and reliable predictions.

Looking forward, the role of ML in public health crises is poised to expand, driven by ongoing advancements in technology and data science. Future developments will likely focus on improving data quality and availability through enhanced data collection methods and robust data management systems. Efforts to standardize data formats and ensure interoperability across different systems will be crucial in overcoming current challenges related to fragmented data. Additionally, advancements in real-time data processing and analytics will enhance the ability of ML models to provide timely and actionable insights during emergencies.

Integrating ML models with other emerging technologies, such as blockchain for secure data sharing and the IoT for real-time monitoring, promises to create more resilient and adaptive surveillance systems. Federated learning allows ML models to be trained across multiple decentralized devices without sharing raw data, can address privacy concerns, and can enhance data security. This approach will enable the development of more robust models that can leverage diverse datasets while maintaining individual privacy.

Future research will likely focus on developing more interpretable and explainable ML models. Transparency in how ML models arrive at their predictions is essential for gaining the trust of healthcare professionals and the public. Explainable AI techniques will help demystify the decision-making process of these models, making it easier to integrate them into clinical workflows and public health strategies.

In conclusion, while ML offers transformative potential for infectious disease surveillance during emergencies, addressing the current limitations and challenges is crucial for realizing its full benefits. Ongoing technological advancements, robust

data governance frameworks, and interdisciplinary collaboration will pave the way for more effective and reliable ML applications in public health crises. As the global landscape continues to evolve, the adaptability and innovation of ML technologies will be key in enhancing our ability to respond to future public health emergencies.

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Assessment of Energy and Resource Efficiency Through Sustainable Planning, Construction, and Operation Using Building Information Modeling (BIM)

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Abstract This article examines the significance of Building Information Modeling (BIM) for sustainable planning, construction, and operation of buildings and infrastructures. The focus is on evaluating energy and resource efficiency through the use of BIM to reduce CO_2 emissions and promote sustainability in the construction sector. The article addresses both the building construction sector and the energy sector, particularly the expansion of grid infrastructure in civil engineering. Despite the potential benefits, these sectors face significant challenges, including the integration of recycled materials and the introduction of digital building logbooks, as required by the EU Circular Economy Action Plan and EU taxonomy. This article highlights the existing barriers and opportunities in the implementation of BIM-driven projects and provides an outlook on necessary measures to achieve sustainability goals.

Keywords Building information modeling (BIM) · Sustainability · Resource efficiency · CO_2 emissions · Circular economy · Energy efficiency · Wood-hybrid construction · Building resource passport · Circular construction · Life cycle assessment · Material efficiency

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1 Introduction

Climate change is one of the most pressing challenges of the twenty-first century, with far-reaching and profound consequences for the environment and society. Global warming, primarily caused by anthropogenic greenhouse gas emissions, is leading to significant changes in the global climate system. These impacts manifest in rising average temperatures, increasing extreme weather events, the melting of polar ice caps and glaciers, and rising sea levels. What was long perceived as a looming threat has now become a reality, as evidenced by recent events such as heatwaves in South and Southeast Asia, floods in Brazil, and wildfires in Canada. One does not need to look beyond Europe's borders: 2023 brought heatwaves and heat-related deaths to Europe as well, with the highest summer temperatures ever recorded since records began [14]. Wildfires in Greece, floods in Germany and Slovakia-the list of incidents is long. These events demonstrate that climate change is increasing the frequency, intensity, and duration of extreme weather events worldwide [8]. To minimize the impacts of such disasters, there is an urgent need to reduce greenhouse gas emissions and improve adaptation strategies [8]. The ultimate goal must be to mitigate climate change and strengthen the resilience of affected communities.

Despite the global consensus on the causes of climate change, there are still skeptics who deny or doubt the existence or human responsibility for climate change. However, the human impact on the climate is supported by numerous studies and reports, such as those of the Intergovernmental Panel on Climate Change (IPCC). These not only highlight the physical foundations of climate change but also the complex interactions between climate, ecosystems, and human activities [6].

Carbon dioxide (CO_2), as one of the main drivers of climate change, is one of the so-called greenhouse gases that contribute to the warming of the Earth's atmosphere. The main sources of CO_2 emissions can be found in various sectors. In addition to transportation, industry, and agriculture, the building and energy sectors are significant contributors. To combat climate change, CO_2 emissions in these sectors must be reduced, and new, sustainable paths must be taken. Sustainability has long ceased to be a peripheral issue in architecture and construction but has become a central task. The urgency to realize environmentally friendly, economically viable, and socially acceptable construction projects increases with each passing day. Yet, the construction industry remains one of the major consumers of resources and emitters of CO_2. The industry must therefore undergo a near-total realignment and integrate sustainable practices throughout the entire life cycle.

The early phases of planning (HOAI LPH 1–3) are already crucial-they define the fundamentals such as material use and the energy concept, thus setting the course for the building's performance. In this context, the use of wood or wood-hybrid construction methods is increasingly finding its way into practice. But how exactly can this use be assessed, and what role will material registers play in terms of sustainability in the future? This article addresses the contribution of BIM in sustainable planning and construction, particularly with regard to reducing CO_2 emissions, and seeks answers to the following research questions.

Part I

Question 1: What challenges and opportunities arise from integrating BIM-driven projects?

Question 2: What indicators and metrics are necessary to track the success of resource-optimized, BIM-based planning in practice?

In the second part, the findings will be applied and evaluated to the distribution networks of utility providers, as the backbone of the energy and climate transition. Distribution networks are crucial for the safe and efficient supply of energy, water, and other resources to households and businesses. They comprise a complex network of pipelines, transformers, and other infrastructure that must ensure continuous and reliable access to essential services.

In this context, the Building Information Modeling (BIM) method is gaining importance in this area as well. Building Information Modeling (BIM), as a digital working method, is finding its first applications in the planning of energy and district heating networks. Building Information Modeling (BIM) as a planning method is not only suitable for above-ground construction but also offers enormous potential in civil engineering. Considering the masses and values buried underground, the further development of sustainable planning strategies is essential: Modern distribution networks increasingly integrate intelligent technologies to improve monitoring, control, and optimization of network operations and to enhance energy efficiency. In this sense, this article aims to provide answers to the following questions in a second part.

Part II

Question 3: What challenges and opportunities arise from the application of Building Information Modeling (BIM) in energy and district heating networks?

Question 4: What contribution can Building Information Modeling (BIM) make in terms of sustainability and resource efficiency in energy and district heating networks.

2 Objectives and Tasks

These research questions aim to explore the potential of Building Information Modeling (BIM) for resource-optimized planning and to highlight practical approaches to improving sustainability in construction. The first part focuses particularly on the fields of action related to the reduction of CO_2 emissions, considering the use of wood in hybrid construction and CO_2-optimized concrete. Additionally, aspects of material recording in the context of a circular economy are examined, taking into account both above-ground and civil engineering measures.

In this context, components of online-based material registers and their benefits are included. These online platforms, such as “Madaster,” support the principles of the circular economy in the construction industry. Their main goal is to document

and register materials and products used in buildings, thereby maximizing their reuse value. Through this systematic recording, the so-called "material passport" is created, containing essential information about the materials used and their reusability.

A special focus is placed on the distribution networks of utility providers and the possibilities of generating added value. Distribution networks are crucial for the efficient and sustainable distribution of energy and other resources. They comprise a complex network of infrastructures that can be optimized through the use of Building Information Modeling (BIM) to increase efficiency and reduce environmental impact. The implementation of BIM in the planning and operation of distribution networks offers the opportunity to develop innovative and sustainable solutions that provide long-term ecological and economic benefits [10].

The aim of this paper is to contribute to a key research area and to expand existing research contributions in the field of sustainable planning.

3 Materials and Methods

The research design of this study is based on a multidimensional, qualitative-empirical approach that combines various data collection and analysis methods to comprehensively answer the research questions. First, a systematic literature review was conducted according to the methodological principles of Kuckartz. The collection and analysis of secondary data were rule-based using MAXQDA software. It was found that the topic of Building Information Modeling (BIM) for improving sustainability is still insufficiently addressed in research, particularly in terms of practical application examples. To fill this gap, several empirical methods were employed:

Expert Interviews: In-depth interviews were conducted with experts who demonstrate high innovation competence in the application of BIM. These interviews aimed to identify specific areas of action and challenges in the implementation of sustainable construction projects.

Case Study: A central component of the methodology is a detailed case study of a pilot project of a municipal building authority. This project focuses on resource- and CO_2-optimized planning using BIM. The case study provided valuable empirical data and allowed the development of concrete application examples and recommendations for action.

Quantitative Survey: To validate the findings, a broad survey was conducted among more than 280 professionals from the energy industry. This survey helped to confirm initial research results and integrate additional perspectives.

Focus Group: Finally, the collected data and results were discussed in a moderated focus group with 15 experts from the fields of construction, sustainability, and digitization. This discussion served as a critical reflection and final validation of the results.

By combining these methods, a well-founded and practical analysis of the action possibilities of BIM for improving sustainability in the construction industry was conducted.

4 Background

Building Building Information Modeling (BIM) has established itself as a transformative method in the construction industry in recent years. It enables a comprehensive, three-dimensional, and data-rich representation of construction projects that encompasses all phases of a building's life cycle-from planning through construction to use and maintenance. By integrating various data sources and facilitating collaboration between participants, BIM offers significant advantages in terms of efficiency, quality, and sustainability. Traditional practices in the construction industry were often characterized by fragmented processes and a lack of integration, frequently leading to inefficient planning, construction delays, and cost overruns. BIM addresses these challenges through optimized planning and design by providing realistic visualizations and improved collaboration between architects, engineers, and builders. This shared use of data models reduces planning errors and accelerates the planning process. Additionally, BIM supports cost and time management, as well as quality assurance, by enabling precise planning of construction processes and resources and virtually simulating construction projects to identify potential problems early on. At the latest, collision checks reveal errors or overlaps during the planning phase, rather than, as was often the case in the past, only on the construction site.

Another significant advantage of BIM in the construction industry is the promotion of sustainability and life cycle management. BIM allows for the analysis and optimization of a building's energy efficiency during the planning phase. Within the digital models, data can be collected and used for the entire life cycle of a building, facilitating maintenance and prolonging the life of the structures. In the energy sector, BIM also shows great potential, particularly in the planning and operation of utility networks and facilities. The energy industry faces the enormous challenge of efficiently planning infrastructure to meet growing demand while minimizing environmental impact. BIM offers several advantages, such as detailed analysis and planning of energy and district heating networks, which increases the efficiency of distribution networks and reduces operating costs. Moreover, BIM enables the integration of sustainability aspects into planning, thereby reducing CO_2 emissions and better integrating renewable energy.

BIM also supports the efficient maintenance and operation of facilities by centralizing the collection and management of maintenance and operating data. This increases the efficiency and reliability of facilities and supports error and risk management by identifying and addressing potential problems early on. However, despite the numerous advantages, BIM has not yet established itself in the energy industry to the same extent as in the construction industry. The sector still faces initial implementation hurdles, including the need for comprehensive training for participants,

the integration of existing systems and databases, and the high initial investment in technology and software. Nevertheless, the growing acceptance and dissemination of BIM in both the construction and energy industries show that this method is a crucial step towards more efficient and sustainable construction and operational processes [7].

4.1 Methodological Fields of Action for Assessing Energy and Resource Efficiency

Building Information Modeling (BIM) offers a wide range of possibilities for assessing energy and resource efficiency and thus improving building performance sustainably during the planning phase. These approaches and methods relate to different fields of action, all of which are based on model-based simulation. These fields of action can be summarized into the following segments.

Energy Analysis: The BIM model forms the basis for conducting energy demand simulations. These simulations help to realistically predict a building's energy consumption and assess various energy-saving measures using variant planning. Additionally, dynamic thermal simulation allows for the analysis of the building's thermal behavior over the course of a year and the identification of optimization potentials in the building envelope and building services.

Life Cycle Assessment: BIM can provide comprehensive data on the materials used and their ecological impacts. This information is essential for conducting a Life Cycle Assessment (LCA), which evaluates the overall ecological footprint of a building. By integrating material registers, the specific properties of the materials used can be combined with an extended range of information. This not only enables a detailed assessment of CO_2 emissions but also allows for the optimization of the ecological footprint through variant planning, particularly with regard to the main trades and their essential material uses. At the same time, the assessment of life cycle costs (Life Cycle Costing, LCC) can combine economic and ecological aspects, leading to sustainable decisions through a cost–benefit analysis.

Resource Efficiency: Through optimized design and precise quantity calculations in BIM, material waste can be significantly reduced, and resource-efficient planning can be achieved. Not only can material savings be assessed, but also the recyclability and reusability. Additionally, environmentally unfriendly materials can be identified early on and replaced with more environmentally friendly products.

Integration of Renewable Energies: BIM models can be used for the planning and integration of photovoltaic systems and solar thermal systems. Through simulations, the optimal placement and size of these systems can be determined. At the same time, the contribution to energy efficiency from systems for heat recovery can be assessed within the model.

Monitoring and Operation: BIM models can be combined with building management systems to continuously monitor building operation and continuously optimize energy efficiency. At the same time, adjustments can be made based on monitoring user behavior to reduce energy consumption. This supports one of the essential sustainability imperatives: not consuming energy in the first place. For renovations during operation, the detailed model data can be used to make targeted adjustments.

Standards and Certifications: BIM can be used to meet the requirements of various sustainability certifications and facilitate the certification process. Compliance with standards such as LEED, BREEAM, DGNB, or the QNG seal can be significantly optimized through digital models. At the same time, the documentation of compliance with legal requirements and standards can be greatly simplified through digital models [1].

4.2 Model-Based Planning to Reduce CO_2-Emissions

In terms of sustainable and circular construction methods, the industry faces new challenges: The EU Circular Economy Action Plan formulates specific targets for the material recovery of construction and demolition waste. These include requirements of the Construction Products Regulation concerning the use of recycled content and the introduction of digital building logbooks. Another goal is to reduce soil sealing. The draft of the EU taxonomy also sets a protection target for the processing of 90% of demolition and construction waste. Essential measures also include life cycle assessment and circularity assessment. At the same time, it is required that at least 50% of the materials used are reused, recycled, or renewable, and no substances of concern under the REACH regulation are used. Another central aspect is the building resource passport, which is firmly anchored in the coalition agreement of the Federal Government for the years 2021 to 2025 and in the coalition agreement of North Rhine-Westphalia for the years 2022–2027. The DGNB Version 2023 also establishes the use of quantitative assessment methods for circular construction and calls for the recognition of digital building resource passports. In addition, minimum shares for sustainable material procurement, especially of wood, as well as minimum recycling shares must be demonstrated. The assessment of deconstruction and recyclability of constructions is carried out in connection with durable and adaptable buildings [6, 7].

In practice, the reduction of CO_2 emissions in the construction industry carries significant weight. The goal of contemporary planning is to reduce resource use and, within these resources, to depict the most CO_2-optimized variant possible. Additionally, the use and consumption of CO_2 emissions throughout the entire life cycle should be kept as low as possible. An important first step toward new, sustainable standards in the construction industry is to record the resources used and assess the CO_2 emissions generated by the construction. By planning with BIM, comprehensive data on the materials used and their environmental impacts can already be analyzed in

the early planning stages. These possibilities for CO_2 savings are demonstrated and mathematically verified in this article using a case study. The case study established a significantly reduced "CO_2 budget" as a maximum allowable budget over the entire life cycle-including deconstruction-from the beginning of planning. This maximum value was based on the requirements of a DGNB Platinum Certification. The requirements for this certification include outstanding fulfillment of sustainability criteria in the areas of ecology, economy, socio-cultural and functional aspects, technology, processes, and location. A building must achieve at least 80% of the achievable points in all assessment categories to receive this highest award from the German Sustainable Building Council.

This ambitious maximum value set the course for the entire planning process, whereby different construction methods, material combinations, and technical solutions were compared in variants. The goal was to identify the ecologically and economically optimal variant. A comparison of variants between wood-hybrid construction, CO_2-optimized concrete, and conventional construction methods, as well as combinations thereof, was carried out. These model-based investigations provided valuable insights into the ecological advantages and potential CO_2 savings. The existing data basis-in the form of a digital twin of the building-enabled the collection of reliable, realistic values, whereas in conventional planning procedures only complex approximations can be determined.

4.3 The Initial Situation-Conventional Construction Methods

The conventional construction method, which mainly relies on the use of reinforced concrete and other traditional materials, inherently causes significantly high CO_2 emissions. Additionally, cement production, as a major component of concrete and thus of the building, is responsible for a substantial portion of global CO_2 emissions. The energy demands for the production and processing of these materials are also high-the enormous consumption of gray energy is characteristic and must be considered in this context. Without specific optimizations and/or the use of sustainable materials, conventional construction leads to a significant ecological footprint. It is therefore imperative to first examine mass-relevant building materials for more environmentally friendly alternatives.

In the case study, a CO_2 budget of a maximum of 439,200 kg was set for the conventional construction method. Starting from this point, CO_2 savings in concrete were first investigated. Standard concretes have an enormous global warming potential (GWP 3). This is due, on the one hand, to the high energy consumption in the production of cement clinker and, on the other hand, to the chemical process of decarbonizing limestone. CO_2-optimized concrete contains 25% by mass of recycled materials and a modified concrete composition, resulting in a global warming potential of GWP 1 [3].

To mitigate these impacts, the use of recycled concrete and wood-solid wood or partial wood structures-was comparatively examined within the underlying case

study. The model calculations provided valuable insights into their CO_2 consumption and potential savings.

Conventional Construction Method with CO_2-Optimized Concrete (V_1)

- The maximum CO_2 budget is 439,200 kg.
- CO_2 consumption is 247,890 kg.
- CO_2 savings amount to 43.5%.

Partial Use Wood with CO_2-Optimizes Concrete (V_2)

- The maximum CO_2 budget is also 439,200 kg.
- CO_2 consumption is reduced to 229,233 kg.
- CO_2 savings increase to 47.8%.

Hybrid Construction Method with CO2-Optimized Concrete (V_3)

- The maximum CO_2 budget remains at 439,200 kg.
- The CO_2 balance is − 4465 kg.
- This results in a CO_2 savings of 100%.

These model calculations illustrate that significant CO_2 savings can be achieved through the use of wood and the hybrid construction method, with the hybrid method even enabling full CO_2 neutrality.

Additionally, the choice of facade materials was examined concerning their environmental impact. The case study calculated three different facade types concerning their circularity indicator, CO_2 savings, and gray energy savings.

V_1: Corten Steel

- Circularity Indicator: 95%.

V_2: New Brick Facade

- Circularity Indicator: 8%.
- CO_2 Savings: 2%.
- Gray Energy Savings: 22%.

V_3: Recycled Brick Facade

- Circularity Indicator: 100%.
- CO_2 Savings: 95%.
- Gray Energy Savings: 98%.

These model calculations show that the recycled brick facade (V_3) delivers the best results in terms of circularity, CO_2 savings, and gray energy savings. The use of recycled materials leads to maximum circularity of 100%, significant CO_2 savings of 95%, and gray energy savings of 98%. In comparison, the new brick facade (V_2) achieves only 2% CO_2 savings and 22% gray energy savings, with a low circularity indicator of 8%. The Corten steel (V_1) has a high circularity indicator of 95%, but the CO_2 emissions and energy consumption are so high that a calculation of the latter was omitted.

These considerations were made possible by the raw material properties and masses stored in the BIM model and showed through variant planning that a total saving of approximately 808.5 tons of CO_2 compared to a conventional new building is possible. These calculations-based on the BIM model-provide valuable insights and contribute significantly to raising awareness regarding the resources used and their impact on the environment.

4.4 Model-Based Planning to Optimize the Circular Economy

The construction industry remains one of the most resource-intensive sectors. In light of increasing raw material scarcity and the need to reduce environmental impacts, the circular economy has established itself as a key strategy for promoting sustainability. Unlike traditional linear economic systems, the circular economy aims to keep materials and products in the economic cycle for as long as possible. This is achieved through reuse, repair, refurbishment, and recycling. The principle is as simple as it is sensible: secondary raw materials become primary raw material sources.

Model-based planning offers decisive advantages in improving material efficiency and promoting sustainable construction practices. The attributes stored in Building Information Modeling (BIM) (data points and information associated with an element in the model) describe its physical, functional, and operational aspects in detail. These attributes can include quantitative values (such as dimensions, costs, or lifespan) as well as qualitative descriptions (such as material type, color, or reusability) and serve the precise planning, analysis, and optimization of projects.

In combination with digital online platforms, such as Madaster, so-called digital building resource passports can be created based on the data, which are already mentioned in the coalition agreement of the federal government. This passport significantly increases the transparency of the building economy by providing information on materials, energy efficiency, CO_2 emissions, and reusability. This approach establishes circularity as a new standard-a crucial step for the industry. At the same time, the building resource passport enables the creation of a life cycle assessment. This life cycle assessment is primarily considered a climate balance, accounting for the entire life cycle of all building materials, from raw material extraction and production to transport and use, and finally to disposal.

The information is available throughout the entire life cycle and allows for data-driven decision-making in both operation and renovation cases. While in conventional buildings, the components used-if not visible-are largely unknown throughout the life cycle, leading to corresponding uncertainties, the available information can also be used to improve construction and deconstruction processes. This facilitates the introduction of a circular economy in the construction industry.

What appears forward-thinking in theory still faces challenges in practice. The industry is at the beginning of a necessarily essential development. While initial marketplaces for recycled building materials and used components are emerging, there is a lack of an overarching authority to establish a unified, ideally nationwide

presence in the sense of the circular economy. Not only do experts see the state as having a duty here. The establishment of comprehensive material registers to promote the reuse of recycled building materials is such a forward-looking field of action that this responsibility should not (exclusively) be placed in the hands of private industry.

Moreover, the approach of circularity still harbors a significant, higher obstacle: the regulatory approval concerning freedom from harmful substances. When building materials are deconstructed, they lose their approval, which hinders their reuse in the new construction sector. A recertification of the building materials is economically unfeasible. This hurdle needs to be overcome as quickly as possible. The use of secondary raw materials allows for environmentally friendly and responsible resource management and should not be hindered by bureaucracy!

4.5 Model-Based Planning to Optimize Network Infrastructures

Building Information Modeling (BIM) offers valuable potential for optimizing the planning and operation of network infrastructures. The digital planning approach enables the creation of detailed models of civil engineering projects, allowing for precise visualization and simulation of various scenarios. This approach helps to identify and resolve potential problems early on, which is particularly crucial in the planning of network infrastructures such as energy, water, and communication networks. At the same time, the integration and coordination of various disciplines and data sources bring significant improvements: Building Information Modeling (BIM) accelerates the planning process and increases efficiency-a decisive advantage in a sector characterized by growth and pressure for change [5, 7].

Simultaneously with the processes described above, Building Information Modeling (BIM) offers the opportunity to optimize energy and resource consumption. By simulating energy flows and resource streams within the BIM model, more sustainable and efficient solutions can be developed. For example, the placement of energy sources and consumers can be optimized to minimize energy losses and increase overall efficiency. Current studies demonstrate the advantages of Building Information Modeling (BIM) in network infrastructure planning. A study by Marzouk and Thabet (2023) shows that the application of BIM-based planning can significantly improve the sustainability of civil engineering projects through precise assessment and optimization. The authors developed a BIM-based tool for assessing sustainability using the Green Pyramid Rating System. This tool enables automated and semi-automated simulation, supporting informed decision-making regarding sustainability [11]. This step towards automated and software-based evaluations is a crucial move towards simplifying sustainability decisions. Another study

examines the integration of Building Information Modeling (BIM) with Convolutional Neural Networks to optimize energy consumption in buildings. This integration leads to more precise and efficient planning by providing detailed energy consumption data, allowing for more accurate analysis and optimization [1].

These examples illustrate that Building Information Modeling (BIM) not only increases planning accuracy but also contributes to resource efficiency and the reduction of environmental impacts. By considering project parameters holistically and enabling simulation and optimization, Building Information Modeling (BIM) represents a powerful tool for sustainable planning and optimizing network infrastructures. Moreover, BIM models contain important information on the values used, such as material properties, technical specifications, energy efficiency, and costs: Material properties include data on the strength, durability, and environmental compatibility of the materials used. Technical specifications include details on pipeline diameters, voltage capacities, and thermal conductivity. Energy efficiency is represented by assessments and calculations of losses and optimization potential. Costs encompass both civil engineering and operating costs, facilitating economic analysis and budgeting.

By integrating this data into a central BIM model, planners and engineers can develop more sustainable and efficient network infrastructures. This leads to optimized costs and minimized environmental impacts, as the comprehensive data enable informed decision-making. Building Information Modeling (BIM) thus promotes the sustainable and economic design of network infrastructures and supports long-term planning and maintenance.

This planning approach offers the potential to become a key technology. Even in network infrastructures, practical strategies are still lacking, which complicates the integration and application of efficient and resource-saving methods. Without these strategies, it is difficult to realize the long-term ecological and economic benefits that could be achieved through sustainable planning and the use of modern technologies like Building Information Modeling (BIM). The development and implementation of such strategies are crucial to achieving sustainability goals while also improving the efficiency and reliability of network infrastructures. A significant aspect is that, due to the gas crisis and the prevailing supply pressure, issues of supply security and economic viability have come to the forefront-at the expense of sustainability. Therefore, it is of enormous importance to identify sustainable strategies quickly, reliably, and without significant personnel effort to restore the balance. In this sense, Building Information Modeling (BIM) can make a valuable contribution.

5 Opportunities and Challenges

The case study demonstrated that BIM-based planning not only significantly simplifies the assessment of harmful CO_2 emissions but can also be verified through reliable analyses. Significant optimizations can be projected through variant planning, as environmentally harmful materials and construction methods can be identified

and thus avoided early on. At the same time, this type of planning enables a new form of awareness-raising regarding the impact of specific construction methods on the environment. Sustainable construction, which integrates ecological, economic, and social aspects, often leads to higher initial investments compared to conventional construction methods. These additional costs result from various factors. First, sustainable materials, such as recycled building materials, wood from certified sustainable sources, or environmentally friendly insulation materials, are often more expensive than conventional alternatives. These materials are subject to strict environmental standards, which increases costs. Concerning the cost–benefit analysis, both in the case study and in the experts' experience, it is evident that the additional costs of a sustainable building amount to between 4 and 7% of the total construction cost. However, it must be noted that a sustainable construction industry is still fundamentally more expensive than a fossil-based construction industry.

Despite the higher initial costs, sustainable construction methods offer long-term economic advantages. Sustainable buildings are generally more energy-efficient, leading to significant savings in operating costs. These savings can offset or even exceed the initial additional costs over the building's lifetime. Moreover, sustainable buildings often have a higher market value and better rentability. Investors and tenants are increasingly willing to pay higher prices for environmentally friendly and energy-efficient buildings. The practice shows that the lack of sustainability in buildings is now being assessed with discounts in property valuation of up to 500 euros per square meter of gross floor area. Despite the clear results of the case study, there are still open tasks for planning optimization using Building Information Modeling (BIM) in early design processes. Simplified assessment tools generally exist that can be used in the early phases of building design to evaluate environmental impacts. However, in practice, it is evident that there are still significant challenges in further improving the effectiveness and accuracy of such tools. These tools use the data contained in BIM models (such as material properties, quantities, and construction processes) to conduct a life cycle assessment. The quality and level of detail of the BIM data play a crucial role in the accuracy of LCA results [12].

The necessarily high quality and level of detail can currently not yet be consistently achieved. Many planners are still at the beginning of building competence in Building Information Modeling (BIM). In Europe, the use of BIM varies widely. Countries such as the United Kingdom, the Netherlands, and the Scandinavian countries (particularly Norway and Sweden) have high BIM adoption, often over 70% in the architecture and engineering industry. In Germany, the use of BIM has increased significantly in recent years, partly due to government initiatives and requirements, particularly in public projects. A 2021 study shows that about 60% of architects in Germany use BIM or plan to do so in the near future [12, 13].

Regarding the circular economy, numerous obstacles still hinder its implementation despite its urgent necessity. From an economic perspective, the transition to a circular economy requires significant initial investments in new technologies and processes. At the same time, recycling and reuse can still be more expensive than using primary raw materials-especially if these are subsidized. Small and medium-sized enterprises also face challenges in market access: They often struggle to access

markets and financing necessary for the transition to a circular economy. The aforementioned regulatory barriers show that the circular economy is still hampered by inadequate legislation; laws and regulations are often not aligned with the needs of the circular economy or are completely lacking. The same applies to the development of necessary infrastructures. Many regions lack the necessary infrastructure for the collection, separation, and processing of waste, which ultimately also affects cost-intensive logistics. Lastly, the development of the circular economy is characterized by a lack of incentives: There are often insufficient financial incentives or tax breaks to motivate companies to switch to circular processes.

6 Summary and Conclusion

Building Information Modeling (BIM) is increasingly establishing itself as a transformative method that significantly improves efficiency and sustainability in the construction and energy industries. BIM enables detailed and model-based planning, providing precise visualization and simulation of building and civil engineering projects, reducing planning errors, and improving collaboration. The transparency resulting from BIM ensures efficient processes from planning to operation. Thus, Building Information Modeling (BIM) is not only transforming the building sector but also civil engineering in energy and water networks. The digital planning method offers comprehensive benefits to both sectors, from precise planning and efficient construction execution to long-term maintenance and sustainability.

A major contribution of BIM lies in optimizing energy and resource consumption. By integrating data and simulating energy flows, more sustainable and efficient solutions can be developed that reduce CO_2 emissions and lower operating costs. Model-based planning thus significantly contributes to increasing sustainability in the construction industry and supports long-term resource efficiency. Moreover, Building Information Modeling (BIM) can accelerate and digitize the approval process in the infrastructure sector.

According to experts, building competence in digital construction is a crucial step to advancing the expansion and digitization of networks. Overall, the application of Building Information Modeling (BIM) shows that this model-based planning significantly contributes to increasing sustainability in the construction industry and significantly reducing CO_2 emissions. In particular, integrating BIM into the planning and operation of network infrastructures can increase efficiency, reduce costs, and improve the overall quality of the infrastructure.

However, these advantages are still limited by various challenges, such as the need for comprehensive urban mining and support for circular construction and renovation. To overcome these obstacles, coordinated efforts from governments, businesses, and society are required. This includes creating appropriate political frameworks, promoting research and development, raising public awareness, and providing financial incentives. These measures could contribute to more sustainable

and resource-efficient construction practices and lead to long-term improvements in the environmental and economic balance of the construction industry.

Particular benefits are offered in terms of a circular economy and the establishment of material registers. The reuse of existing building materials and, thus, the once-bound CO_2 emissions should be given the highest priority. This offers enormous potential for both the construction industry and the network infrastructure of the energy industry, especially in terms of sustainability and cost-efficiency. However, current regulatory barriers must first be overcome. At the same time, it is essential to break free from the prevailing resistance to change. Companies and consumers must turn away from linear business models and recognize the advantages and necessity of a circular economy..

6.1 Application of Findings to the Research Questions

The preceding findings allow for answering the research questions and emphasize the importance of a holistic approach to the management and evaluation of complex networks and buildings through Building Information Modeling (BIM).

Question 1: What challenges and opportunities arise from integrating wood-hybrid construction methods in BIM-driven projects?

Challenges

Material Properties and Data Integration: Accurately capturing and integrating the material properties of wood and hybrid materials into BIM models can be complex. These materials vary in strength, durability, and behavior during the construction process, requiring precise modeling and simulations.

Norms and Certifications: Complying with building regulations and certification requirements for wood-hybrid construction methods can be challenging, especially when these regulations are not fully aligned with the use of such materials.

Cost and Economic Viability: The higher costs associated with certified sustainable wood and related construction methods can pose an economic challenge, especially when compared to conventional building materials.

Opportunities

Sustainability and CO_2 Reduction: Wood-hybrid construction methods offer significant advantages in terms of sustainability and reducing CO_2 emissions. Wood, as a renewable resource, has a lower environmental impact compared to traditional building materials like concrete and steel.

Innovative Construction Methods: Integrating wood-hybrid construction methods into BIM-driven projects enables innovative construction approaches and fosters the development of new, efficient construction methods that offer both ecological

and economic benefits. Despite these advantages, there are challenges, particularly regarding the finite nature of the wood resource and sustainable forestry.

Question 2: What indicators and metrics are necessary to continue the success of resource-optimized BIM-based planning in practice?

Indicators and Metrics

CO_2 Emissions: A key indicator is the measurement and reduction of CO_2 emissions caused by construction processes and materials. BIM-based life cycle assessments (LCA) provide robust data bases for optimizing construction processes.

Energy Efficiency: The energy efficiency of buildings and network infrastructures is also crucial. BIM models offer simple comparison and optimization opportunities within construction methods and technologies used, as well as in operation.

Material Efficiency: The quantity and reusability of the materials used are additional important metrics. This includes assessing material waste, recycling rates, and the use of secondary raw materials.

Cost–Benefit Analysis: The economic evaluation of construction projects, including initial investments and long-term savings through sustainable construction and operational methods, remains one of the most important indicators.

Question 3: What challenges and opportunities arise from the application of Building Information Modeling (BIM) in energy and district heating networks?

Challenges

Data Integration and Interoperability: Integrating BIM data with existing infrastructure systems and software platforms can be complex. Interoperability and ensuring seamless data exchange are key challenges.

Training and Acceptance: Implementing Building Information Modeling (BIM) requires comprehensive training for the professionals involved and overcoming resistance to new technologies and working methods.

Opportunities

Efficiency Gains: Building Information Modeling (BIM) offers the potential to make the planning, construction, and maintenance of energy and district heating networks more efficient. Through precise modeling and simulation, bottlenecks can be identified and resolved before they become problems.

Sustainability and Resource Efficiency: Applying Building Information Modeling (BIM) allows for better integration of sustainability aspects, such as optimizing energy consumption and using renewable energy, leading to a more sustainable infrastructure overall.

Questions 4: What contribution can Building Information Modeling (BIM) make in terms of sustainability and resource efficiency in energy and district heating networks?

Building Information Modeling (BIM) can make a significant contribution to the sustainability and resource efficiency of energy and water networks by enabling a holistic view and management of the networks. This includes precise planning and simulation of energy flows, identification of optimization potentials, and integration of renewable energies. By using Building Information Modeling (BIM), efficiency can be increased, costs reduced, and environmental impacts minimized. Additionally, BIM supports the long-term maintenance and operation of network infrastructures by providing detailed and up-to-date data essential for informed decision-making and efficient operational processes.

6.2 Discussion

On the path to new sustainability standards, practical solutions are still lacking, which presents a significant challenge, especially for the inherently slow-moving energy and real estate sectors. These sectors are being asked to completely shift their thinking and actions within a short decade. This shift is necessary to achieve climate goals and significantly reduce environmental impacts.

Challenges

Lack of Practical Solutions: Despite numerous theoretical concepts and models, there is a lack of practical, implemented examples that could serve as role models. This hinders the widespread acceptance and implementation of new standards.

Resistance to Change: Many companies are accustomed to linear business models and show resistance to change. This is exacerbated by uncertainty regarding the payback periods of new technologies and methods.

Regulatory Barriers: Existing legal frameworks are often not aligned with the needs of the circular economy and sustainable construction methods. This complicates the introduction of new, environmentally friendly practices.

Costs and Investments: The high initial investments required for sustainable technologies and materials present an economic barrier, especially for small and medium-sized enterprises.

Opportunities

Innovation and Research: Increased investment in research and development can lead to innovative solutions that are practically tested. This includes developing new building materials, optimizing construction processes, and integrating digital technologies like Building Information Modeling (BIM).

Collaboration and Networking: Collaboration between governments, companies, and research institutions can accelerate the development and implementation of sustainable solutions. Joint efforts and the exchange of best practices are crucial for making progress.

Awareness and Training: Targeted education and training programs can raise awareness among companies and consumers about the benefits and necessity of sustainable practices. This promotes the acceptance and implementation of new standards.

Political Framework: Creating appropriate political frameworks and financial incentives can motivate companies to invest in sustainable technologies. This includes subsidies, tax breaks, and funding programs.

The transformation towards new sustainability standards requires a holistic approach and coordinated efforts at all levels. Despite existing challenges, the shift to sustainable practices offers significant opportunities for both the environment and the economy. Through innovation, collaboration, and targeted political measures, practical solutions can be developed and implemented that pave the way for a more sustainable future.

This contribution follows the research of Abualdenien et al., Borrmann et al., as well as Fonseca Arenas and Shafique, who evaluate the integration of Building Information Modeling (BIM) in the early planning phases of buildings. They conclude that Building Information Modeling (BIM) enables consistent management and evaluation of models. They also confirm that the comprehensive data base allows for improved accuracy of life cycle assessments (LCA). They further explain that standardized data models like Industry Foundation Classes (IFC) promote the vendor-neutral exchange of digital building models and thus facilitate collaboration in the construction industry. Their findings support the results of the case study presented here, demonstrating that BIM-based approaches, combined with LCA, play a significant role in reducing greenhouse gas emissions in the construction industry and thus contribute to the development of sustainable buildings [2, 4, 9].

6.3 Further Research Needs

In this context, the development and implementation of sustainable measures to reduce greenhouse gas emissions and to adapt to the inevitable consequences of climate change are gaining importance. These measures are essential to strengthening the resilience of societies and protecting biodiversity. The present discourse has been able to highlight the key aspects and challenges of climate change and the potentials of Building Information Modeling (BIM) in a compressed manner. For research, it is essential to continue to demonstrate how scientific findings can be integrated into effective and actionable climate policies. A central research need lies in the further development of Building Information Modeling (BIM) as a tool for promoting sustainability in the construction industry and energy infrastructure. In particular, the integration of BIM with life cycle assessment (LCA) and circular economy approaches requires deeper investigation. Additionally, there is a need for practice-oriented studies that accompany and evaluate the implementation of BIM in real construction projects to better understand the practical challenges and opportunities.

Another important area of research concerns the interoperability and data integration of BIM software with existing systems and platforms. Standardized data models and interfaces should be further developed to promote seamless data exchange and collaboration between various actors in the construction and energy sectors. In addition, building competence in dealing with BIM and raising awareness of the importance of sustainability in construction and energy infrastructure is of great importance. This requires the development of educational and training programs that convey both technical skills and a deep understanding of sustainable practices.

Finally, research should focus more on creating political frameworks that promote the application of BIM and sustainable construction practices. This includes developing incentives, regulations, and standards that motivate companies and public institutions to comprehensively implement sustainable technologies and methods like BIM. Overall, there is an urgent need for interdisciplinary research that combines technical, economic, and social aspects to advance the development and implementation of sustainable solutions in the construction and energy infrastructure sectors. Only through a holistic and coordinated research effort can the full potential of Building Information Modeling (BIM) be realized, contributing to the fight against climate change.

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The Use of Gamification in Time Management

Eva Ticina and Juraj Chebeň

Abstract Amid the rapid rise of the fourth technological revolution, Gen Z faces productivity challenges due to distractions. This study explores how gamification can address time management issues specific to this generation. While prior research has examined gamification in time management, little focus has been given to Gen Z's unique perspective. This study contributes by analyzing perceptions, behaviors, and characteristics related to gamified time management. A survey with statistical analysis and interviews with text analysis were conducted to test hypotheses. Findings suggest that while gamification can improve time management and productivity, reliance solely on gamification is insufficient due to limited motivational impact. The study recommends integrating gamification into educational curricula and suggests businesses explore gamified time management apps, while also employing diverse strategies to enhance effectiveness.

Keywords Gamification · Time management · Gen Z · Productivity · Survey · Eisenhower matrix

1 Introduction

Chuah and Kabilan [1] implicitly note that as the rapid development of the 4th technology revolution is becoming especially obvious, humanity tends to use technologies much more than ordinary pen and paper. For example, once in a time, people joke that they even forgot how to write. Nowadays, smartphone has become a thing that accompanies us everywhere in our everyday life. It is a thing that we absolutely cannot forget to take along.

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According to the survey results published in Fox News by Clark [2], 3 in 4 managers say that GenZ (born 1997–2012 and are 11–26 years old) is the most onerous generation to deal with. A majority (65%) of respondents find it more common to fire Gen Z workers compared to those from other generations. The primary reasons for this perception include Gen Z employees being easily distracted and exhibiting a lack of effort, motivation, and productivity.

The confluence of these factors highlights a pressing need for innovative approaches to address the time management and productivity challenges faced by young people in this technology-driven era. This research, called The Use of Gamification in Time Management, aims to explore how gamification can be a useful solution. Gamification, by integrating elements of play and competition into traditionally mundane tasks, presents an opportunity to enhance engagement, motivation, and time management skills.

The benefits of the use of gamification for business education were discussed in a number of studies [3–7] and were provided lots of significant advantages of using it. These studies highlighted how gamification can improve learning, engagement, and motivation in educational settings. These positive outcomes in the realm of education suggest that applying gamification to time management, especially for younger generations like Gen Z, holds significant promise in addressing the challenges posed by today's technology-driven environment.

The primary objective of this study is to contribute to the research fields of gamification in time management, time management and application development for gamified time management applications.

In this case study we try to answer the following research question:

RQ1 How gamification can be a useful solution to address the time management and productivity challenges faced by young people in this technology-driven era?

In this article we try to verify the following hypotheses:

Hyphotesis 1: The productivity app would be more user-friendly if it didn't use fancy font styling and minimized scrolling by including a search button.
Hyphotesis 2: Gen Z (13–26) are less successful in managing their time in their studies or at work than other generations. They are less willing to improve their performance than other generations.
Hyphotesis 3: Gen Z (13–26) are less able to prioritize their tasks than other generations.
Hyphotesis 4: Gen Z (13–26) are less experienced in time management than other generations.
Hyphotesis 5: Gen Z (13–26) use more gamified time management apps than other generations.
Hyphotesis 6: Gen Z (13–26) believes that time management tools that include game elements can improve their skills.
Hyphotesis 7: Gamified time management apps improve users' motivation.

The article is divided into four main parts. The first section covers fundamental concepts in time management, gamification, and application development.

We describe principles, concepts, and methods of time management. Moreover, we present reviews of existing applications for time management, gamified applications for skill development, and gamified applications specifically for time management. We emphasize the importance of gamification for teaching and skill development. Furthermore, this part contains information about application development for management purposes, including the application lifecycle with a focus on user-friendly design. The second part outlines the aims of the article. The third section is devoted to the methodology. In the fourth section, we present the data collected, results, and findings from the statistical analysis of the questionnaire and text analysis of the interview. Finally, we provide a discussion in which we delve into the key findings, offer an interpretation of these findings, outline the limitations, and suggest practical applications of our findings. We also provide recommendations for further scientific investigation.

2 Time Management Concepts

Aeon and Aguinis [8] note that time management has been a subject of contemplation for centuries, reflecting humanity's enduring quest to optimize time use. However, there is no universally agreed-upon definition of time management. Some define it as a blend of time assessment, goal setting, planning, and monitoring activities, while others emphasize the subjective and self-controlled effort to use time efficiently. Different disciplines view time management from various angles, focusing on personal time structure or the ability to adhere to plans and make accurate time estimates.

"Time management has a moderate influence on job performance, academic achievement, and wellbeing" [9].

Time management is "a set of practical techniques that can optimize time and achieve significant results in their activities" [10].

Chebeň [11] defines time management as a set of knowledge and skills that lead to the efficient use of time, to maximize work productivity and achieve set goals with minimal stress. Knowledge and skills can be acquired through studying activity execution, observing the behavior of others, performing similar or related tasks in the past, receiving feedback on activities performed, and understanding and objectively assessing one's abilities.

Aeon et al. [9] specify that time management is the practice of utilizing knowledge and skills to efficiently use time to maximize work productivity and achieve set goals while minimizing stress. This includes acquiring knowledge and skills through studying activity execution, observing the behavior of others, performing similar or related tasks in the past, receiving feedback on activities performed, understanding, and objectively assessing one's own abilities. Time management is often regarded as a solution to cope with an increasingly busy and time-constrained society, where people strive to coordinate and prioritize their tasks efficiently.

2.1 Time Management for GenZ

In an age defined by digital connectivity, information abundance, and shifting career landscapes, the art of time management has never been more vital. For Generation Z, the cohort born roughly between the mid-1990s and early 2010s, mastering time is about productivity and navigating a world brimming with opportunities and distractions [12].

This generation, often called Gen Z, has distinctive characteristics and experiences shaping their approach to time. They are true digital natives, born into a world of smartphones, social media, and instant access to knowledge [13]. Both ambition and awareness of well-being marks their aspirations. In a rapidly changing job market, they value adaptability and continuous learning.

Time management is especially crucial for Generation Z, who, as digital natives, utilize various digital tools for managing their schedules, making it important to tailor time management education to their familiarity with technology. Fromm and Read [13] emphasize that Gen Z faces unique challenges such as information overload and multitasking, which can affect their focus and productivity, underscoring the need for skills in prioritizing and efficiently managing their time. Additionally, this generation's work habits involve flexible schedules and independent work environments, requiring robust self-management skills.

Saxena [14] highlights that Gen Z is goal-oriented and values continuous learning and adaptation to technological changes, which necessitates effective time management strategies to achieve their goals and keep up with ongoing education. They also place a high importance on wellness and self-care, suggesting that their time management should incorporate time for personal well-being.

Overall, Gen Z's approach to time management is intertwined with their use of technology, pursuit of educational and personal goals, and a strong commitment to wellness, requiring a tailored approach to develop their competencies in managing time effectively [13, 14].

2.2 Time Management Principles

"Students find themselves procrastinating on tasks they do not like but must be done" [15]. "Clear goals and time-management skills rank as the most important factors in personal or academic success" [16].

"Good time management can facilitate productivity and minimize stress, hence, contribute towards work effectiveness and academic success" [17].

Broadbent, and Poon [18] research also has shown that self-regulated learning strategies, including time management is positively correlated with academic success.

Various studies shate that time management can improve the success rates [15, 19–22].

Das [23] determine the following principles of time management:

- Time analysis,
- Identifying time thieves,
- Setting priority goals,
- Formulating an action plan.

According to Das [23], the application of time management principles can be done in the following ways:

- Avoiding procrastination,
- Focusing on highly prioritized tasks,
- Controlling perfectionism,
- Setting personal deadlines,
- Considering energy levels throughout the day,
- Managing task interruptions,
- Monitoring task completion progress.

From Chebeň [11] perspective, in time management, it is important to:

- Recognize the varying importance of individual tasks and be able to define priority tasks.
- Prioritize tasks with firmly established completion deadlines.
- Improve one's ability to estimate the time required for each task.
- Have a quality assistant (in case you are in a managerial position with assistant requirements).
- Clearly define goals and set timeframes for their completion.
- Plan not only on a daily basis but also consider medium and long-term goals.
- Make a list of tasks that need to be performed during specific time periods.
- Divide very demanding tasks into several smaller tasks.
- Allow a time buffer for each task in case of unexpected and unforeseeable events when planning.
- Delegate less important tasks to other parties when possible.
- Eliminate "time thieves" that distract from work.
- Be able to accurately estimate the duration of individual tasks (anticipate time requirements).
- Plan the daily work schedule and allocate breaks (with the help of modern technology).
- Focus on measurable and time-bound goals.
- Avoid performing multiple tasks simultaneously and minimize multitasking for less important tasks.
- Strive to work consistently during time intervals when you are most productive and focus primarily on the most important and challenging tasks (if you have the flexibility to choose your work hours).
- Have an eye for detail, maintain order in your affairs, and archive information effectively (to eliminate time wasted when searching for important information).

- Know how to decline certain activities and say "no" when it is objectively reasonable.
- Avoid overworking and know how to rest in order to recharge your energy.

2.3 Key Aspects of Chosen Methods of Time Management

To Do Method. Chebeň [11] clarifies that the *To Do* method is a relatively straightforward approach to time management that falls into the second generation of time management techniques. It involves recording tasks and reminders for each day or a short time frame, similar to a shopping list. The core idea is to have a clear understanding of what tasks to accomplish and when to complete them. This method provides an overview of completed and unfinished tasks, allowing for the rescheduling of uncompleted tasks if necessary. In electronic form, this method can be implemented using calendar applications where tasks can be color-coded or highlighted for better organization. Tasks can be improved by assigning priorities, ordering them from most important to least important, and marking completed tasks.

Time Snapshot of the Day. Chebeň [11] underscores that the *Time Snapshot of the Day* involves recording all work-related and non-work activities during the day, including breaks between activities, to gain an understanding of how a workday flows. This method can help optimize the time spent on various tasks, prioritize activities, and eliminate time-wasting elements.

Time Blocks. Newport [24] writes that the *Time Blocks* method, also known as the Time Blocking Method, is similar to the To Do Today approach. It emphasizes the importance of focusing on one task at a time within specific time blocks. If the allocated time blocks prove insufficient, they can be adjusted for the following day or month. People can apply this method to plan and execute a wide range of activities, enhancing their productivity by efficiently allocating their time.

Natural Laws Technique as Presented by Benjamin Franklin. The Natural Laws Technique for time management, as presented by Fiering [25], emphasizes aligning one's daily schedule with natural rhythms and personal effectiveness. Franklin advocated for structuring activities around the times of day when one is most mentally and physically capable. His method includes a focus on early rising, reflecting personal productivity peaks, and adhering to a disciplined routine that balances work, personal development, and rest, all while making consistent self-improvements and tracking progress. Franklin's approach is about understanding and utilizing one's natural inclinations and rhythms to maximize efficiency throughout the day.

This involves reflection for continuous improvement.

The Eisenhower Matrix. According to the Jinalee and Singh [26], The Eisenhower Matrix is a time management method that helps prioritize tasks by categorizing them based on their urgency and importance. The matrix is divided into four quadrants:

urgent and important tasks to do immediately, important but not urgent tasks to schedule for later, urgent but not important tasks to delegate, and neither urgent nor important tasks to eliminate. This method allows individuals to focus on what truly matters, reducing time spent on less important activities. It's a practical approach to organizing your workload and managing your time more effectively.

3 Gamification for Teaching and Skill Development

In this section, we will explore the concept of gamification as a powerful tool for enhancing teaching and fostering skill development. Gamification, the practice of applying game-like elements and principles to non-game contexts, has gained significant recognition as an innovative approach to engage learners and motivate them to acquire new skills. This chapter delves into the various ways gamification can be effectively employed in education and skill-building, shedding light on its applications, benefits, and the potential it holds for transforming traditional teaching methods into dynamic and interactive learning experiences.

Gamification is the use of game mechanics, aesthetics, and game thinking to engage people, motivate action, promote learning, and solve problems [27].

In gamification, unlike in a game where the main goal is entertainment, the game is merely a tool to achieve objectives, primarily increasing attention and motivation [28].

Saxena [14] affirms that Gamification is a dynamic and innovative approach that utilizes game-like elements to enhance engagement and motivation in various learning contexts, particularly within education. It is a response to the challenges posed by traditional pedagogical methods, which often lack the key element of fun. Gamification leverages features like points, badges, and leaderboards to incentivize participation and performance. This approach is particularly relevant in addressing challenges related to student engagement and motivation in the educational sector.

Saxena [14] underscores the importance of gamification in education for Generation Z, emphasizing its alignment with their characteristics and learning preferences. Gamification enhances engagement by incorporating interactive elements like points, badges, and leaderboards, which are particularly effective for students known for their short attention spans. Additionally, it leverages Gen Z's technological proficiency by integrating digital tools and platforms into the learning process, making it intuitive and accessible.

According to the viewpoint of Saxena [14], gamification also supports Gen Z's preference for socialization and collaborative learning through team-oriented elements and community-based evaluations. It offers personalized learning paths and instant feedback, catering to individual learning styles and providing quick assessments of progress. Furthermore, the visual and multimodal aspects of gamification cater to Gen Z's visual learning preferences, making information engaging

and easy to absorb. This approach not only enhances their educational experience but also develops skills like problem-solving and persistence, essential for their entrepreneurial spirit.

Gamification in studying is important for Gen Z because it aligns with their preferences, enhances engagement, and leverages their comfort with technology [12–14]. Acoording to Saxena [14] it caters to their visual learning style, need for social interaction, and desire for personalized experiences. By incorporating game elements, such as competition and instant feedback, gamification makes learning more enjoyable and effective for Generation Z students.

Gamification can be included in the educational innovation for service innovation [29].

3.1 Gamification for Management Skill Development

In today's rapidly evolving business landscape, the demand for effective management skills is higher than ever before. The ability to lead teams, make informed decisions, and adapt to changing circumstances is critical for the success of organizations and the career advancement of individuals. To meet these demands, innovative approaches to skill development have emerged, and one such approach that has gained considerable attention is gamification. Chapter explores the exciting realm of gamification as a tool for honing and enhancing management skills.

Various studies stated that gamification can improve learning skills [30, 31]. Management skill development has traditionally relied on various forms of training, workshops, and educational programs. While these methods have proven valuable, gamification offers a fresh perspective on how we can engage, motivate, and empower individuals to become more effective managers.

3.2 Gamification in Project Management

The applicability of project management tools has increased [32].

Farooq et al. [33] research reveals that Gamification in project management education is a powerful tool for engaging students, developing both technical and soft skills, and providing a practical learning experience. It offers a dynamic and interactive approach to PME, with the potential to cover a wide range of knowledge areas. However, it should be used in balance with traditional methods and should consider the neglected areas of procurement and stakeholder management. Gamification has the potential to transform project management education by making it more engaging and effective. Gamification is employed as a teaching tool in PM courses, and it involves creating game scenarios to simulate real-world project management situations.

For example, Lino et al. [34] created in their study the Project Management Game that based on the obtained data can improve project management skills of the users.

Moreover, the study by Silvius and Silvius [35] reviewed existing project management games. Their analysis revealed significant variations in professionalism, functionality, and technical support among the apps, with some developed as entrepreneurial experiments and others as professional products.

3.3 Gamification in HR Management

Orenič [36] explores the use of gamification in HR management as a method to engage employees and enhance HR practices. This strategy integrates game-like elements into recruitment, training, and employee engagement processes, making them more interactive and enjoyable. Gamification not only improves motivation and productivity but also boosts employee retention during demanding recruitment phases. It fosters a sense of social connection through elements like leaderboards and badges and is particularly effective in e-learning programs. Moreover, gamification reduces workplace stress and is preferred by employees, thereby addressing issues related to unengagement and enhancing overall organizational success.

4 Application Development for Management Purposes

"Mobile technology has undergone a drastical evolution" [37]. C "Mobile technology is an exceptionally fast-growing field that is closely connected with our work and day-to-day lives" [38].

Huang and Benyoucef [39] observe that recent data indicates that the majority of the world's population, approximately 97%, owns either a cell phone or a smartphone, highlighting the widespread use of mobile devices. These modern smartphones have evolved into more than just communication tools and are now significant drivers of transformation in various industries. The smartphone industry has experienced substantial growth and continuous technological advancements, expanding its market reach.

According to Statista [40], the mobile app ecosystem has witnessed explosive growth since the introduction of Apple's App Store in 2008, now boasting over 5 million apps collectively on the App Store and Google Play Store as of 2021. In the realm of operating systems, Android has solidified its dominance with a commanding 70.93% share of the global smartphone market, while iOS holds a substantial 28.37% share, with Samsung being a central player in this landscape. This surge in the mobile app industry is reflected in a projected global revenue of $420.80 billion by 2023, with gaming, education, productivity, and business segments contributing significantly. In

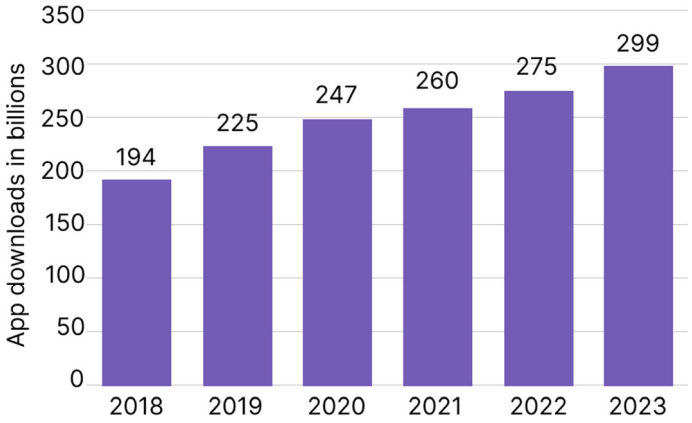

Fig. 1 Number of mobile app downloads worldwide from 2018 to 2023 (in billions)

addition, users globally downloaded nearly 77 billion mobile apps in the first half of 2023, with revenue primarily derived from advertising, in-app purchases, and paid apps (Fig. 1).

As indicated by Statista [41], the mobile app landscape continues to witness impressive growth, with a total of 299 billion downloads across various segments as of 2023. Games account for a significant share with 134 billion downloads, while education, productivity, and business segments also contribute with 6 billion, 8 billion, and 4 billion downloads, respectively.

Thomas and Devi [42] suggests that a notable trend in the app market is the prevalence of free downloads, which has led users to be more hesitant to pay for app downloads. The increasing popularity of apps is largely driven by social networking and messaging apps on a global scale. The success of app categories in major app stores, such as Android and Apple, can be gauged by their penetration rates among users, reflecting the evolving app ecosystem (Fig. 2).

Thomas and Devi [42] affirms that as of September 2019, the global penetration of Android app categories reveals that productivity is a prominent segment with a 92% adoption rate, while tools, communication, and business apps enjoy even higher adoption at 99%. It's crucial for app developers to focus on user retention and engagement to ensure the longevity and success of their apps. While smartphones often have numerous apps installed, user attention is concentrated on a select few, emphasizing the importance of keeping users engaged and providing feedback to foster app growth.

According to Statista [40] females spent on 17% more time on applications than males.

Huang and Benyoucef [39] research reveals that the mobile gaming industry is poised for further innovation driven by faster 5G networks, advancements in augmented reality, virtual reality, and the integration of blockchain technology. These

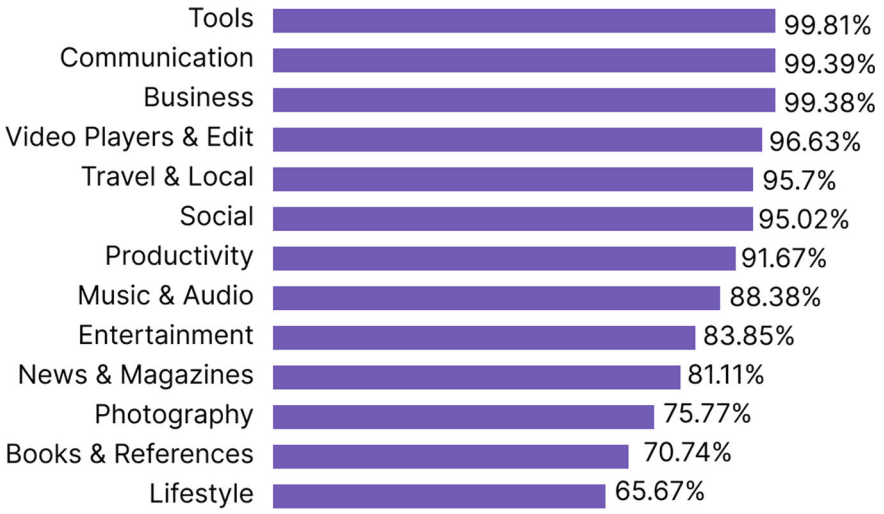

Fig. 2 Penetration of Android app categories globally as of September 2019

developments have the potential to solidify the growing interest in the metaverse and its integration into mobile gaming.

Mobile app development is a vital aspect of the digital landscape, powering an ever-expanding industry that has become integral to virtually every aspect of modern businesses [39].

4.1 App Design for GenZ

Saxena [14] characterizes Generation Z, born mid-1990s to early 2010s, as tech-savvy, heavily reliant on digital devices, and prominent in visual and interactive learning. This generation, also known as Gen Z, is becoming a significant part of the workforce. Their brain architecture, influenced more by their environment than genetics, shows a heightened development in the visual processing area.

When designing content for Generation Z, also known as Pivotals, it's essential to understand and embrace specific strategies that resonate with this digitally savvy and socially conscious group.

According to Fromm and Read [13], it is crucial to humanize your brand to appeal to Generation Z. This demographic prefers brands that exude personality and seem like a natural part of their everyday lives. Authenticity is key; Gen Z is highly skilled at recognizing insincerity and values genuine interactions over efforts to appear trendy. Moreover, because their attention span averages just eight seconds, it is essential to grab their interest quickly with compelling visuals, videos, and captivating narratives right from the start.

Fromm and Read [13] also emphasize the importance of a seamless and consistent user experience across all platforms, which should be tailored to fit the specific context of each medium. Creating a sense of community and engaging in meaningful two-way conversations can build loyalty and make Gen Z consumers feel valued. Humor is another critical element; Gen Z appreciates quirky and offbeat humor and responds well to content that mirrors their unique comedic style.

Finally, while personalization can enhance the content experience, it must not come at the expense of privacy. Security and transparency are paramount; clear communication about data use and protection helps build trust with Gen Z consumers. By integrating these principles, brands can create a strategy that not only appeals to Generation Z's preferences but also fosters a genuine connection with them.

4.2 Motivation in the Workspace

Elomaa [43] highlights that motivating Generation Z in the workplace presents unique challenges compared to previous generations. Generation Z places less emphasis on work as a central aspect of their lives. Nevertheless, understanding the motivating factors for this generation is crucial. They are highly educated, confident, and enter the workforce with high expectations. Key motivational factors for Generation Z include self-development, advancing opportunities, and work tasks that challenge them to learn and grow.

Elomaa [43] underscores that this generation is motivated by intrinsic factors such as empowerment, job security, and affective organizational commitment. The study suggests that affective organizational commitment is the most critical intrinsic factor for Generation Z, followed by training and empowerment. Extrinsic factors like promotion, training, and rewards also play a role in motivating Generation Z. However, the research indicates that intrinsic motivators have a more substantial impact on their work motivation compared to extrinsic ones. Additionally, Generation Z values non-monetary rewards, such as positive feedback and recognition, over monetary compensation. They prefer working in a team environment, and the company culture and work community strongly influence their work motivation.

5 Methodology

5.1 First Part

The first part of our article is dedicated to the *literature review and content analysis.* We selected relevant literature, systematically processed it, analysed its content and presented findings.

Table 1 A set of logical keywords

Time management	AND	Gamification
Time management		
Serious games		
Gamification		
Application development for time management		
Serious games	AND	Time management

A search of published literature was conducted to gather related researches on the themes *time management*, *gamification in time management* and *development of gamified time management applications*. Three databases, Scopus, Google Scholar, and IU Library, were searched from the year 2012 to 2024 using a set of logical keywords and syntax specific to each database (Table 1).

Works that were not related to the topic were excluded. To ensure including only substantial scientific work in this review, we only considered journal articles, published books and dissertations. Using the exclusion criteria, we have chosen 40 journal articles as relevant for my case study and used 26. We also used information from some trustworthy web pages.

To gather the relevant information about existing gamified time management apps we were ought to include and web pages of those apps.

5.2 Second Part

In the second part, we performed an empirical research. To verify our hypotheses, we used a mixed-methods approach. we performed a *survey* which is quantitative method and an *interview*, which is a qualitative method.

We conducted empirical research because we needed to apply the knowledge gained from the literature review to practice and then collect and analyse data for verify hyphoteses.

Questionnaire is a quantitative method, which is why we needed to perform a statistical analysis. Interview is a qualitative method, which is why we needed to group the obtained data into meaningful themes or categories and perform text analysis.

Survey

First of all, we performed a survey. Our goal was to gather relevant data to perform statistical analysis in order to verify particular hyphoteses. To analyse the data obtained from the survey, we performed *statistical analysis.*

Google Forms was used to create a survey which included 25 questions.

The survey was distributed to students of Comenius University, employees of the IT company Anwell, participants on SurveySwap and members of SurveyCircle. The

period for collecting responses was from April 12, 2024, to April 21, 2024. A total of 64 respondents completed the survey. Due to one respondent not selecting their age, one response had to be discarded, resulting in 63 responses being considered for the statistics.

The collected data were first cleaned and structured using Excel. Subsequently, the data were analyzed using Python in Jupyter Lab, focusing on descriptive statistics such as means, standard deviations, medians, and summary statistics. To test the hypotheses, we conducted t-tests. Additionally, we utilized and Power BI software to create visual graphs.

Interview

Secondly, we interviewed 9 people from the different age groups to get a broader understanding of some important questions. To analyse the data obtained from the interview, we grouped the data into meaningful themes or categories and performed *text analysis.*

6 Article Results and Discussion

6.1 Feedback from the Questionnaire

We conducted the questionnaire to confirm the following hypotheses and collect valuable information in order to contribute to the research fields of time management, gamification in time management, and gamified time management development.

Google Forms was used to create a survey which included 24 closed questions. Among these were 4 identification questions. 8 questions investigating the role of gamification in time management. 10 questions aimed at exploring the relationship between time management and Gen Z 2 questions focused on gathering information about important people‘s behaviors (Table 2).

To better understand the specific needs of Gen Z in comparison with other age groups, we analyzed survey data with particular attention to the age of the respondents. The survey included 39 representatives from Gen Z, accounting for 61% of the total participants, and also explored the views of older generations.

The participant pool consisted of 35 women and 28 men, resulting in a higher number of female respondents. Most of the Gen Z participants have recently graduated from high school or obtained a bachelor’s degree. Notably, 50% of the respondents are students, which is particularly significant when analyzing the Gen Z population. A portion of the Gen Z cohort is entering the workforce, while others continue their education.

Hyphotesis 1: Gamified Time Management Apps Improve Users’ Motivation.

We obtained data from Question 29, which only users with prior experience using gamified time management apps could answer (Fig. 3).

Table 2 Characteristics of the survey respondents

Variable categories		Frequency	Percentage
Age	13–18	17	26.98
	19–26	22	34.92
	27–30	9	14.29
	31–41	7	11.11
	42 +	8	12.70
Sex	Male	28	44.44
	Female	35	55.56
Education level	Elementary school	1	1.59
	High school	20	31.75
	Bachelor	24	38.10
	Master	16	25.40
	Doctoral or equivalent	2	3.17
Occupation	Student	32	50.79
	Employee in private sector	15	23.81
	Employee in public or state sector	10	15.87
	Unemployed	6	9.52

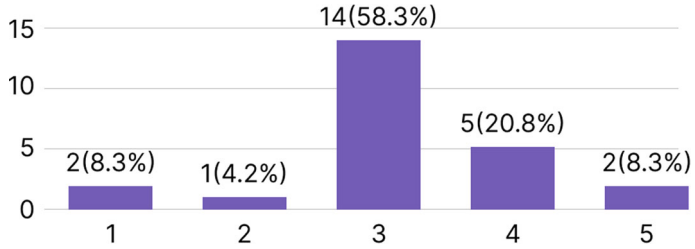

Fig. 3 How have such apps impacted your motivation and productivity levels?

All of 63 respondents were counted. Mean score of 3.17 and standard deviation of 0.96 indicate that on average, users rate their change in motivation due to gamified time management apps slightly above neutral (3), with some variation around this average. We tested the Hyphotesis that the mean motivation score for users differs from 3 (neutral impact) and performed one-sample t-test. t-statistic of 0.85 tells that the observed average increase in motivation scores for users using gamified time management apps is not statistically significant. The p-value of 0.405 is much greater than 0.05, indicating that there is no statistically significant difference from the neutral impact score of 3.

This suggests that the *data does not support the Hyphotesis that gamified time management apps significantly improve the motivation levels of users.*

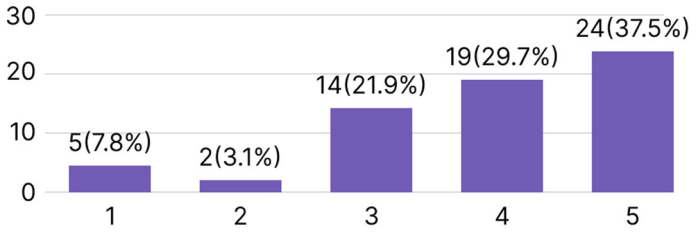

Fig. 4 Do you believe that tools for time management that include game elements can improve time management skills?

Hyphotesis 2: **Gen Z (13–26) Believe That Tools for Time Management That Include Game Elements Can Improve Time Management Skills.**
We obtained data from Question 22 (Fig. 4).

39 GenZ respondents were counted with the mean score of 4.05, and standard deviation of 0.97. 24 other generations' respondents were counted with the mean score of 3.67, and standard deviation of 1.37. These results indicate that, on average, Generation Z has a higher belief in the effectiveness of gamified time management tools compared to other generations. To determine if this difference is statistically significant, We performed a t-test on these means. We got t-statistic of 1.20 and p-value of 0.238.

The p-value of 0.238 indicates that there is *no statistically significant difference in the belief in the effectiveness of gamified tools for improving time management skills between Generation Z and other generations, despite the observed higher average belief among Gen Z.* This finding suggests that while Gen Z might have a slightly higher average belief in the benefits of gamified tools, the difference is not statistically significant.

Thus, it can be concluded that people across all generations share the belief that time management tools incorporating gaming elements can enhance time management skills.

Hyphotesis 3: Gen Z (13–26) Use More Gamified Time Management Apps Than Other Generations.
We obtained data from Question 27 (Fig. 5).

The summary statistics show the proportion of respondents who have used gamified time management apps: GenZ—43.6% and other generations—37.5%. These results suggest that a slightly higher proportion of Gen Z respondents use gamified time management apps compared to other generations. To determine if this difference is statistically significant, we performed a t-test on these means. We got t-statistic of 0.47 and p-value of 0.639. The p-value of 0.639 indicates that there is *no statistically significant difference between Generation Z and other generations in their usage of gamified time management apps*, despite the observed higher proportion among Gen Z.

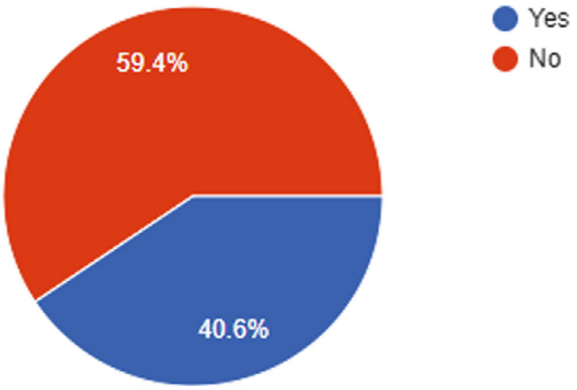

Fig. 5 Have you previously used any apps or tools for time management or productivity that include game elements?

This finding suggests that while Gen Z might slightly lead in the usage of such apps, the difference is not statistically robust enough to confirm that Gen Z use more gamified time management apps than other generations.

However, the data indicates that a significant portion of respondents (40.6%) have previously used gamified time management applications, suggesting that this field holds considerable potential.

Hyphotesis 5: Gen Z (13–26) are Less Successful in Managing Their Time in Their Studies or at Work Than Other Generations. They are Less Willing to Improve Their Performance Than Other Generations.

We obtained data from Questions 8 and 9 (Fig. 6).

39 GenZ respondents were counted and 24 respondents of other generations (Table 3).

The difference in time management success between Gen Z and other generations is statistically significant at the 5% level. This suggests that Gen Z rates themselves lower in time management success compared to other generations. The difference in

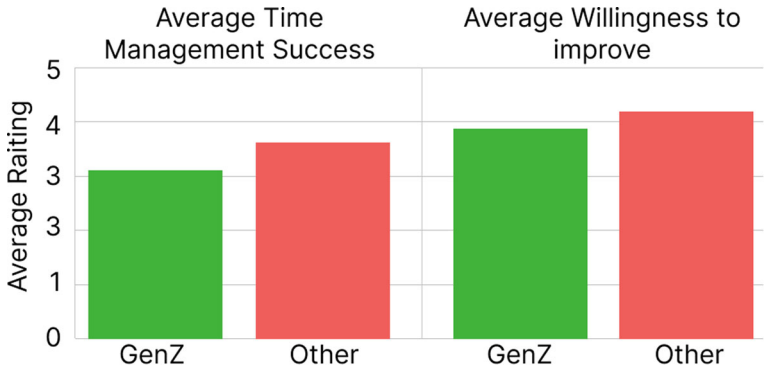

Fig. 6 Average time management success and willingness to improve

Table 3 Hyphotesis 5 table

	Age	Mean	Standard deviation	t-statistic	p-value
Success in managing time	GenZ	3.03	1.14	− 2.02	0.048
	Other	3.58	1.02		
Willingness to improve	GenZ	3.85	1.11	− 1.15	0.255
	Other	4.17	1.05		

willingness to improve between Gen Z and other generations is not statistically significant. This implies that there is no substantial difference in willingness to improve performance between the two groups.

These findings *partially support my Hyphotesis: Gen Z appears to be less successful in managing their time compared to other generations, but they do not significantly differ in their willingness to improve their performance.*

Hyphotesis 6: Gen Z (13–26) are Less Able To Prioritize Their Tasks Than Other Generations.

We obtained data from Questions 20 and 21 (Fig. 7 and Table 4).

39 GenZ respondents were counted and 24 respondents of other generations (Table 4).

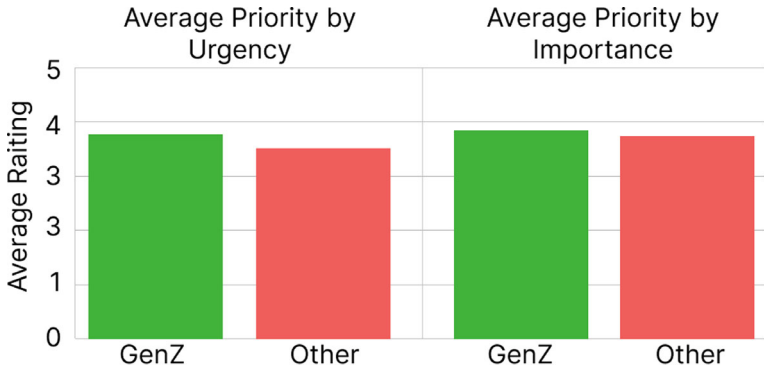

Fig. 7 Average ability to prioritize tasks

Table 4 Hyphotesis 6 table

	Age	Mean	Standard deviation	t-statistic	p-value
Average ability to prioritize tasks by urgency	GenZ	3.74	0.99	0.93	0.358
	Other	3.77	1.09		
Average ability to prioritize tasks by importance	GenZ	3.46	1.28	0.51	0.613
	Other	3.63	1.10		

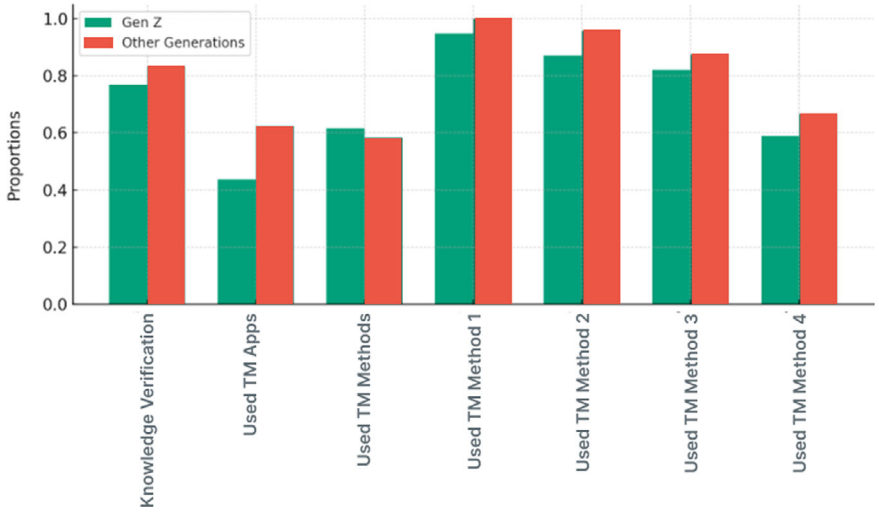

Fig. 8 Comparison of time management experience between GenZ and other generations

There is no statistically significant difference in the ability to prioritize tasks by urgency between Gen Z and other generations. There is also no statistically significant difference in the ability to prioritize tasks by importance between Gen Z and other generations.

These findings *do not support the Hyphotesis that Gen Z are less able to prioritize their tasks than other generations. In fact, the descriptive statistics suggest that Gen Z rates slightly higher on average in these skills.*

Hyphotesis 7: Gen Z (13–26) are Less Experienced in Time Management Than Other Generations.

We obtained data from Questions 5, 6, 7, 10, 12, 15, 17 (Fig. 8 and Table 5).

From the summary, we observe that other generations generally show a higher percentage in understanding and using time management apps and some methods. However, the use of time management methods overall is slightly lower for other generations compared to Gen Z. There are no statistically significant differences in these aspects of time management between Gen Z and other generations. This consistent lack of significant difference suggests that the *Hyphotesis stating Gen Z are less experienced in time management compared to other generations is not supported by the data.*

Finnaly, we can state that GenZ representatives are experienced in time management as well as other generations.

Table 5 Hyphotesis 7 table

	Age	Affirmative answers in %	t-statistic	p-value
Understands time management	GenZ	76.9	− 0.62	0.54
	Other	83.3		
Used time management apps	GenZ	43.6	− 1.47	0.15
	Other	62.5		
Used time management methods	GenZ	61.5	0.25	0.81
	Other	58.3		
Used time management method 1	GenZ	94.9	− 1.43	0.16
	Other	100		
Used time management method 2	GenZ	87.2	− 1.27	0.21
	Other	95.8		
Used time management method 3	GenZ	82.1	− 0.59	0.56
	Other	87.5		
Used time management method 4	GenZ	59.0	− 0.61	0.55
	Other	66.7		

Hyphotesis 8: The Productivity App Would be More User-Friendly if it Didn't Use Fancy Font Styling and Minimized Scrolling by Including a Search Button.

We obtained data from Question 30, which only users with prior experience using gamified time management apps could answer (Fig. 9).

All of the 63 respondents were counted. With mean score of 3.25, standard deviation of 1.29 with a t-statistic of 1.5569 and p-value 0.1246 which is greater than 0.05, we failed to reject the null Hyphotesis. This suggests that there *isn't statistically significant evidence to conclude that removing fancy font styling and minimizing scrolling by including a search button makes the productivity app significantly more user-friendly, based on the responses provided.*

Below are the results of responses to other important questions in my questionnaire (Fig. 10).

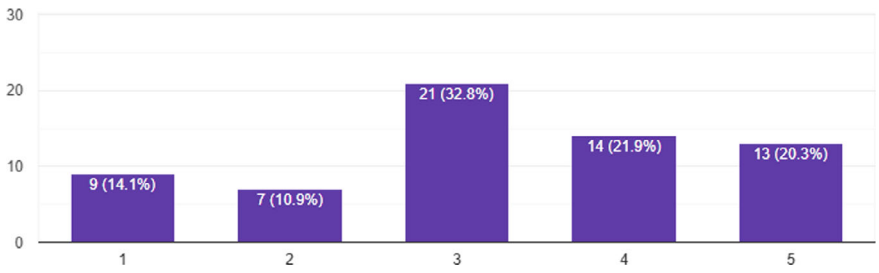

Fig. 9 Do you think the productivity app would be more user-friendly if it didn't use fancy font styling and minimized scrolling by including a search button?

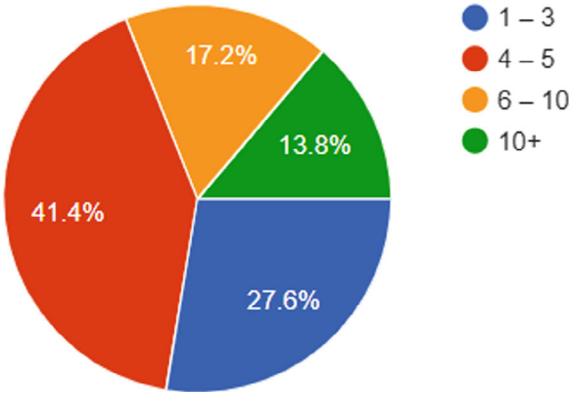

Fig. 10 How many tasks per day do you usually plan?

It can be observed that most people plan between 4 and 5 tasks a day (Fig. 11). Most respondents prefer watching videos (Fig. 12). Challenges and quests are the most engaging and helpful (Fig. 13).

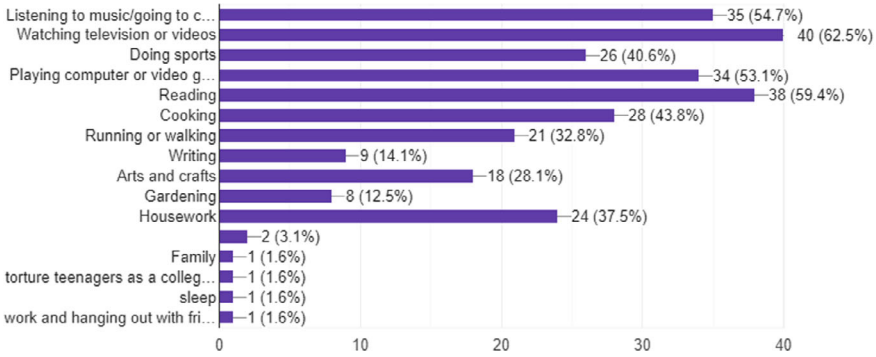

Fig. 11 What are your preferences for free time?

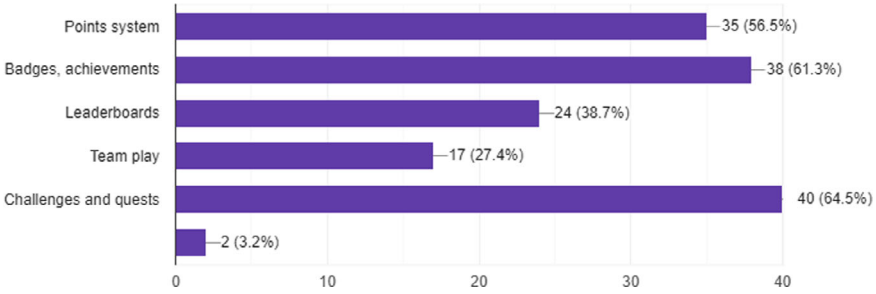

Fig. 12 Which gamification features do you find most engaging or helpful?

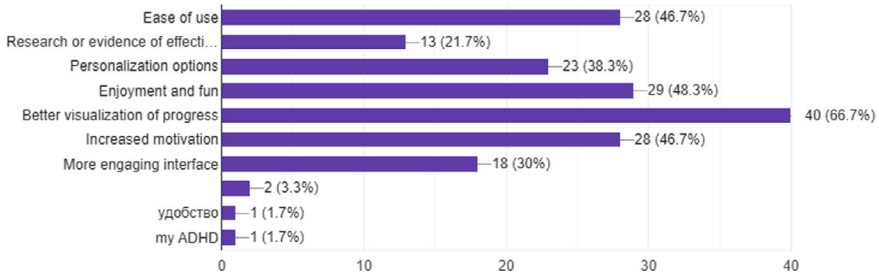

Fig. 13 What would make you choose a gamified tool over a traditional time management tool?

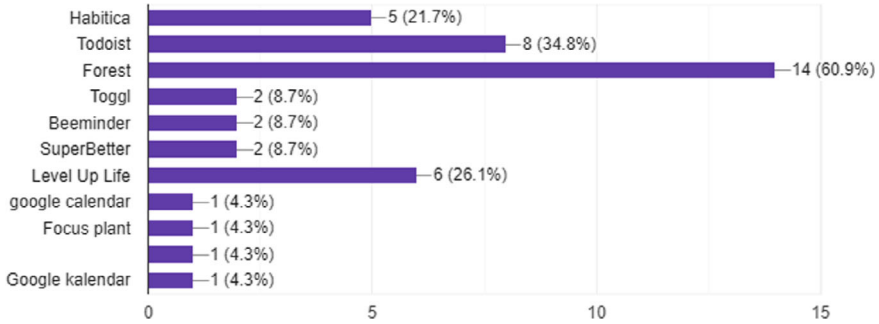

Fig. 14 Which tools or apps that include game elements have you used to manage your time or enhance productivity?

The most important is better visualization of progress. Next one is enjoyment and fun, and the third one is increased motivation (Fig. 14).

Most of people used Forest to focus on their tasks.

Suggestions on How Participants Would Like Us to Improve App Design.

The majority of respondents appreciated the design, and several provided intriguing suggestions for enhancements. These include adding fluffy animals, incorporating color themes, and introducing competitive elements. Others suggested improving the avatar customization options, adding mini-games, and enabling the sharing of progress with friends. Additionally, the app could be enhanced by having a character guide the user, simulating a friend who studies alongside them. Some graphical elements also need refinement.

6.2 Feedback from the Interview

To get a broader understanding of the important questions, we conducted an interview (Table 6).

Table 6 Characteristics of the interview respondents

Variable categories		Frequency	Percentage
Age	13–18	2	22.22
	19–26	3	33.33
	27–30	1	11.11
	31–41	1	11.11
	42 +	2	22.22
Sex	Male	5	55.56
	Female	4	44.44
Education level	Elementary school	2	22.22
	High school	2	22.22
	Bachelor	2	22.22
	Master	2	22.22
	Doctoral or equivalent	1	11.11
Occupation	Student	5	55.56
	Employee in private sector	3	33.33
	Employee in public or state sector	1	11.11

Since the study primarily focuses on Gen Z, we interviewed 5 Gen Z representatives and 4 people from other generations. The balanced gender representation ensured a comprehensive perspective. All of the Gen Z participants were students and held at most a bachelor's degree.

The first question aimed to establish the demographic profile of the interviewees, including their age, sex, occupation, and level of education.

Questions 2 and 3 were focused on gathering feedback on the overall design and user-friendliness of the interface.

The fourth question invited specific suggestions on how the app's design could be improved. This kind of open-ended query allows participants to provide practical insights that might not be covered by more direct questions. It helps me understand user expectations and identify potential areas for enhancement.

Questions 5 to 7 sought to ascertain the app's effectiveness in helping users manage their tasks. These questions aim to validate the core functionalities of the app as a productivity tool.

Question 8 addressed the app's utility in fostering continuous personal improvement, such as tracking habits and tasks. This is particularly relevant in gamified applications where long-term engagement and behavioral changes are key objectives.

Question 9 explored additional gamification features that could enhance motivation. This feedback is vital for making the app more engaging and ensuring sustained user interaction, which is a core advantage of gamification.

The final question 10 aimed to determine whether the simplicity of the app's design, such as font styling and the inclusion of a search function, contributes to or detracts from its user-friendliness. This question is crucial for gaining a deeper understanding of why Hyphotesis 8 was rejected in the interview.

By addressing these areas, the interview seeks to gather comprehensive user feedback that can guide the developers in refining the app's design and functionality to

better meet the needs and preferences of its intended user base. This feedback loop is essential for creating a product that is not only useful but also enjoys high user adoption and satisfaction (Table 7).

Overall, respondents reacted positively to the app's design, with the majority finding it appealing and suitable for the intended tasks. While the design was generally well-received, one user suggested it could be made brighter to enhance its visual appeal.

Participants agreed that the app is user-friendly, emphasizing its ease of use and accessibility.

The design was repeatedly described as appropriate for the task, indicating a strong alignment between the app's features and its intended use. However, there is recognition that some aspects still require refinement.

To further enhance the user experience, several improvements were proposed: adding more fluffy animals and plants to create a more engaging interface, introducing customizable color themes, and implementing timers and reminders for better time management. Additional suggestions included incorporating a pop-up window that allows users to complete tasks for accumulating bonuses, introducing trading options, providing fixed rewards, and adding premium features like AI.

Older generations expressed some reservations about the need for gamification features.

According to the interview it is a good idea not to use fancy font styling, but search button is unnecessary.

Generally, users responded positively to the design of the app. They found it suitable for the intended tasks, with a good visual appeal and user-friendly interface. However, suggestions such as making the design brighter and improving the visual components indicate that while the design is fundamentally strong, there is room for enhancement to cater to individual preferences.

6.3 Discussion

The analysis does not support the Hyphotesis that gamified time management apps significantly improve user motivation levels. This implies that user motivation does not significantly increase or decrease.

The findings suggest that while Gen Z might have a slightly higher average belief in the benefits of gamified tools, the difference in perceptions between Gen Z and older generations is not statistically significant. This indicates that people across all generations share a similar belief that time management tools incorporating gaming elements can enhance time management skills.

The data also show that while Gen Z might slightly lead in the usage of gamified time management apps, the difference is not statistically robust enough to confirm that Gen Z uses these apps more than other generations.

Table 7 Interview results

Question	Answer
What is your overall evaluation of the design?	A. I generally like it. Good idea. A new perspective on an old issue B. Positive C. Nice design D. Meticulously developed with a focus on the user. There could be work done on the visual components, but overall it satisfies everyone. In such apps, convenience is crucial, and it seems to be the target here E. I like the design; it's pleasing to the eye and intuitive F. Excellent, 9/10. Why not 10? It could be a bit brighter G. I like it H. Good I. 10/10
Do you think the interface is user friendly?	A. Yes B. Quite convenient, compact C. Not very clear about convenience D. Generally, yes E. Yes F. Yes G. Yes H. Yes I. Yes
Please tell your suggestions on how you would like us to improve this app design	A. I would be pleased if there were fluffy creatures and plants, maybe a pot with roses or something of that sort B. Larger font C. Simplify as much as possible, remove distracting icons and images D. Work on the icons, on the background of some screens E. I like everything. I can provide more details after using the app F. A bit brighter G. Install a timer for task completion; a month calendar H. Timer + reminders I. Everything is satisfactory

(continued)

Table 7 (continued)

Question	Answer
Do you think that this app will be useful to create a list of tasks that need to be completed?	A. Yes B. Suitable for large tasks C. I didn't actually see a task list here D. I consider E. Yes, definitely F. Yes G. Yes H. Yes I. Yes
Do you think that this app will be useful to create a list of tasks that need to be completed in advance?	A. Yes B. Yes C. I actually didn't see a task list here D. Definitely E. Yes F. Yes G. Yes, but with a reminder H. Yes I. Yes
Do you think that this app will be useful to divide the day into blocks of time dedicated to specific tasks?	A. Yes B. Yes C. Yes, it's suitable for daily scheduling D. Naturally E. Yes F. Yes G. Yes H. Not really I. Yes
Do you think that this app will be useful to do a reflection for continuous improvement? To track your habits, tasks and tendencies?	A. Yes B. To some extent C. It's unclear which tool will help in analyzing habits and such… D. Yes E. Maybe not entirely, as it's a mobile app, and people tend to go to Instagram/ YouTube and similar distracting apps as soon as they turn on their phones F. Yes G. Yes, yes H. Yes, but not always I. Yes

(continued)

Table 7 (continued)

Question	Answer
What other gamification elements do you think could be used to improve user motivation?	A. It would be nice to have a pet and the ability to do something nice for your pet—improve its quality of life B. More informative animation C. Game elements are unnecessary unless it's specifically for teaching children daily routines D. A pop-up window with the option to complete a task for additional bonuses, which accumulate. This would enable the possibility to obtain a premium account. The main functionality needed by the average user would be preserved, while new features with AI integration or something else useful would be available only to premium users E. I can't answer F. I don't know G. Points that could be used beneficially for oneself, for example, to buy a new avatar or a skin for the app H. Rewards for timely completed tasks, penalty points for uncompleted or untimely tasks I. God knows
Do you think the productivity app would be more user-friendly if it didn't use fancy font styling and minimized scrolling by including a search button?	A. I like the standard, large, bold, and easily readable font B. Doubtful C. Fonts must be clearly readable; the search button is useful but will probably be rarely used D. No, some elements must be present in the design. People are lazy creatures; having a button readily accessible is more convenient than searching for something E. No, I don't see anything in the design that would hinder perception F. Yes G. Yes H. Yes I. No

However, the data indicates that a significant portion of people across all generations have used gamified time management applications, suggesting considerable potential in this field.

The results collectively support my Hyphotesis that the app design is user-friendly and suitable for various time management methods, enhancing its appeal as a gamified time management tool.

My findings partially support the Hyphotesis: Gen Z appears to be less successful in managing their time compared to other generations, but they do not significantly differ in their willingness to improve their performance.

These findings do not support the Hyphotesis that Gen Z is less able to prioritize tasks than other generations. In fact, Gen Z rates slightly higher on average in these skills.

The Hyphotesis that Gen Z is less experienced in time management compared to other generations is not supported by the data. The data suggest that representatives of Gen Z are as experienced in time management as other generations.

The results do not provide statistically significant evidence to conclude that removing fancy font styling and minimizing scrolling by including a search button makes the productivity app significantly more user-friendly.

By testing these hypotheses, we contributed to the research fields of gamification in time management, time management, and the development of gamified time management applications.

Based on the conducted study, gamification generally appears to be a viable solution to address the time management and productivity challenges faced by young people in this technology-driven era. The results also show that many people across all generations have previously used gamified time management applications and strongly believe that these can enhance motivation. However, the actual improvement in user motivation is minimal. Thus, while gamification can be a useful tool, it should not be overly relied upon for its positive effects.

My findings do not fully align with the theory proposed by Huang and Benyoucef [39] concerning usability design features specific to productivity apps. My study suggests that while avoiding complex font styles is beneficial, including a search button may not be advantageous for time management apps focused on tasks and habits.

We concur with Thomas and Devi [42] that productivity apps constitute a very appealing segment and can be highly beneficial for businesses.

We disagree with Saxena [14] and Farooq et al. [33] that gamification is particularly crucial for Generation Z students. While teachers and educators can integrate gamification into the learning process, they should not focus solely on it and should explore other options.

The study does not support the results reported by Fox News from Clark [2], which found that Gen Z employees are easily distracted and exhibit a lack of effort, motivation, and productivity. My findings suggest that Gen Z is experienced enough in time management and can prioritize tasks slightly better than other generations. While Gen Z appears to be less adept at managing their time compared to other generations, their motivation to improve their performance does not significantly differ.

This study included only 39 Gen Z individuals and 24 representatives from other generations worldwide. Therefore, it is particularly important for future research to be more targeted. For example, focusing solely on Gen Z representatives from a specific country could yield a better understanding.

Our recommendation for educators is to incorporate gamification elements into studies for time management. However, it is crucial not to rely solely on gamification and to integrate other methods more extensively.

We recommend that businesses enter the field of gamified time management apps because, according to the study and market research, this field is very promising. Moreover, while employers can use gamification to enhance the time management skills of their workers, they should not depend exclusively on the results of gamification. They should also incorporate other methods alongside gamification.

For developers of gamified time management applications targeting Gen Z, we advise making the app useful for creating 4–5 tasks per day, including videos, challenges, and quests. Moreover, visualize progress as effectively as possible and try to use other gamified features to improve user motivation. The goal is to make the app enjoyable and fun for the users.

7 Conclusion

The article is divided into four main parts: Part 1—Introduction to Key Concepts: This section provides a foundational understanding of time management, gamification, and application development. It explores time management principles, reviews existing time management applications, and discusses the role of gamification in skill development. Additionally, it covers the application development lifecycle with an emphasis on user-friendly design. Part 2—Objectives: The second part outlines the aims and goals of the article. Part 3—Methodology: The third section details the research methods and approaches employed throughout the study. Part 4—Results and Analysis: In the final section, we analyze results from interviews and surveys, the data collected, and the key findings derived from this research.

The study suggests that gamification could effectively address the challenges of time management and productivity among young people in today's tech-centric world. However, it is important to not depend too heavily on gamification for its positive impacts. The data reveals that Gen Z has a particularly positive perception of the gamified time management app's design, demonstrating a favorable view towards such applications. Additionally, the findings indicate that individuals from various generations have engaged with gamified time management tools and hold a strong belief in their potential to boost motivation. Nonetheless, the actual increase in motivation resulting from these apps is minimal.

By testing hypotheses, we contributed to the research fields of gamification in time management, time management, and the development of gamified time management applications.

The analysis of the gamified time management app indicates that while these apps do not significantly boost user motivation levels, they are well-received across all age groups, including Gen Z. The data shows that people across generations believe that gamified tools can enhance time management skills, although Gen Z does not significantly use these apps more than other generations. A substantial number of users from various generations have engaged with gamified apps, suggesting promising potential in this area. The study also confirms that the app's design is user-friendly and adaptable to various time management methods, which supports its attractiveness as a gamified tool. Additionally, findings reveal that Gen Z is as capable of managing time and prioritizing tasks as other generations, challenging the notion that they are less skilled in these areas. Overall, the research contributes to understanding gamification in time management and its application development, providing insights crucial for future enhancements in this field.

The practical outcome of this project is a fully developed application crafted based on insights gathered from surveys and interviews about gamified time management apps. These apps hold significant potential, particularly among Gen Z users.

This study was limited to 39 Gen Z participants and 24 individuals from other generations globally. This highlights the need for more focused future research. Concentrating exclusively on Gen Z from a particular country might provide deeper insights.

We suggest that educators integrate gamification into time management curricula, but it is essential to not solely depend on gamification and to consider incorporating a broader range of methods.

We also recommend that businesses explore the promising field of gamified time management apps. While gamification can enhance employees' time management skills, reliance should not be placed solely on it; other strategies should be employed in conjunction with it.

For developers crafting gamified time management apps for Gen Z, it is advisable to design the app to handle 4–5 tasks daily and to include engaging features like videos, challenges, and quests. It is crucial to visualize progress effectively and enhance the app with other gamified features to boost user motivation, ensuring the app is enjoyable and entertaining.

In conclusion, this article offers both theoretical insights and practical applications, contributing valuable knowledge to the field and providing a tangible solution designed to meet specific user needs.

Appendix

Appendix 1: Survey Questions

1 How old are you?

   a. 10–12

b. 12–18
c. 19–26
d. 27–30
e. 30–41
f. 42 +
g. No answer

2 What is your gender?

Male
Female

3 What is your highest level of education?

a. Elementary school
b. High school
c. Bachelor
d. Master
e. Doctoral or equivalent

4 What is your occupation?

a. Student
b. Employee in public or state sector
c. Employee in private sector
d. Unemployed

5 Could you please answer what is time management?

a. Time management is merely documenting each task you do without prioritizing them, assuming all tasks hold equal importance.
b. Time management is organizing and allocating time to tasks to enhance productivity and efficiency.
c. Time management is focusing solely on multitasking, trying to perform as many tasks as possible simultaneously without strategic planning.
d. Time management is the practice of completing tasks only under pressure and at the last minute, relying on spontaneous bursts of effort rather than planned scheduling.

6 Did you use time management apps before?

Yes and I am still using it
Yes, but I have given up
No

7 Did you use any time management methods during your life?

a. Yes
b. No

8 Are you successful in managing your time in your studies or at work?

1	2	3	4	5
Not	Partly Not	Neutral	Partly yes	Yes

9 How willing are you to improve your performance?

1	2	3	4	5
Not	Partly Not	Neutral	Partly yes	Yes

10 Have you ever created a list of tasks that need to be completed?
Yes

b. No

11 Have you ever created a list of tasks that need to be completed in advance? (to get a visual overview of how your time will be spent.)

a. Yes
b. No

If yes than:

12 How many tasks per day do you usually plan?

a. 1–3
b. 4–5
c. 6–10
d. 10 +

13 Have you ever divided the day into blocks of time dedicated to specific tasks? (Focus on one activity at a time)

a. Yes
b. No

14 Have you ever used a time management method that helps you organize your daily routine and habits to match your natural patterns and personal values, aiming to improve yourself and keep a well-balanced life?

a. Yes
b. No

15 What are your preferences for free time? (multiple choice)

a. Listening to music/going to concerts
b. Watching television or videos
c. Doing sports
d. Playing computer or video games

e. Reading
f. Cooking
g. Running or walking
h. Writing
i. Arts and crafts
j. Gardening
k. Housework
l. Other

16 How well are you able to prioritize your tasks by urgency?

1	2	3	4	5
Min				Max

17 How well are you able to prioritize your tasks by importance?

1	2	3	4	5
Min				Max

18 Do you believe that tools for time management that include game elements can improve time management skills?

1	2	3	4	5
Not	Partly Not	Neutral	Partly yes	Yes

19 Which gamification features do you find most engaging or helpful? (multiple choice)

a. Points system,
b. Badges, achievements,
c. Leaderboards,
d. Team play,
e. Challenges and quests
f. Other___

20 What would make you choose a gamified tool over a traditional time management tool? (multiple choice)

a. Ease of use
b. Research or evidence of effectiveness
c. Personalization options
d. Enjoyment and fun

e. Better visualization of progress
f. Increased motivation
g. More engaging interface
h. Other

21 Have you previously used any apps or tools for time management or productivity that include game elements (points system, level up, leaderboards, etc.)?

a. Yes
b. No

If yes than:

22 Which tools or apps that include game elements have you used to manage your time or enhance productivity? (Multiple Choice)

a. Habitica
b. Todoist
c. Forest
d. Toggl
e. Beeminder
f. SuperBetter
g. Level Up Life
h. Other__

23 How have such apps impacted your motivation and productivity levels?

1	2	3	4	5
Decreased	Partly Decreased	No change	Partly Increased	Increased

24 Do you think the productivity app would be more user-friendly if it didn't use fancy font styling and minimized scrolling by including a search button?

1	2	3	4	5
Not	Partly Not	Neutral	Partly yes	Yes

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Cybersecurity Surveillance in the Context of the Employee's Right to Privacy

Filip Petrinec and Ivan Makatura

Abstract Preventing data leakage and monitoring information assets are crucial to safeguarding sensitive information within organizations. However, these practices must be approached with careful consideration for employees' fundamental right to privacy. This article delves into the balance between data protection measures and the rights of employees to privacy in the workplace. This study navigates the complex terrain of data security by examining current best practices in security monitoring and ethical data privacy considerations. Effective data leakage prevention strategies should align with the principles of transparency and accountability, ensuring that security measures do not infringe upon individual privacy rights. By exploring the ethical dilemmas and practical challenges inherent in data protection practices, this article aims to contribute to understanding how organizations can maintain robust security measures while respecting employees' right to privacy in the modern workplace.

Keywords Surveillance · Data leakage prevention · Security monitoring · Employee's privacy · Data protection · Workplace security · Security ethics · Privacy rights

1 Introduction

In today's digital age, organizations increasingly implement cybersecurity surveillance measures to protect sensitive information and prevent data breaches. However, these measures often raise significant ethical and legal concerns, particularly regarding employees' rights to privacy.

This article examines how organizations can implement effective data leakage prevention strategies that respect individual privacy in the workplace. Our research

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aims to contribute to ongoing discussions about the intersection of security and privacy, providing insights that inform policy-making and foster environments where these critical aspects coexist harmoniously.

2 The Current State of Knowledge in the Scientific Literature

The balance between employees' right to privacy and employers' need for security monitoring presents a complex challenge. Research in this area suggests various perspectives and solutions. The current state of knowledge on security monitoring and employee privacy rights reflects a nuanced understanding of the balance between organizational security and personal privacy. Here's a summary of key insights:

- Legal Protection and Workplace Surveillance: The European Convention on Human Rights and the General Data Protection Regulation (GDPR) have been instrumental in outlining legal protections for employee privacy in the context of workplace surveillance. These frameworks emphasize the necessity of balancing employer interests with employee privacy rights [1].
- Digitalization and Privacy Transformation: The advent of digital technologies and remote employment has significantly altered the landscape of employee privacy. The lack of internationally binding labor standards in this domain suggests a growing need for localized regulation and judicial legitimization to protect privacy rights effectively [2].
- Monitoring and Privacy Rights: The balance between employer monitoring and employee privacy rights is delicate. Principles of legitimacy, proportionality, and transparency are crucial in navigating the conflicting interests of workers and employers, especially concerning communication surveillance [3].
- Employee Privacy Boundaries: The clash between the employer's need to protect business interests and the employee's right to privacy is critical. The proportionality and necessity of data collected through technical monitoring means are under scrutiny, advocating for strict rules and transparency in data collection and usage [4].
- Workplace Surveillance Analyzis: An analyzis of workplace surveillance practices highlights the need for a balanced approach that respects employee privacy while addressing organizational needs. The ethical and psychological impacts of surveillance on employee satisfaction and privacy are significant concerns [5].
- Organizations can balance employees' privacy and security needs by developing fair and lawful monitoring policies, considering principles such as transparency, necessity, and proportionality. Information security standards like ISO 17799 can guide these efforts [6].

- Privacy is argued to be a moral right, and while workplace surveillance can be justified in some circumstances, there is generally a presumption against infringing on privacy. The benefits of surveillance to both employees and employers need careful scrutiny to justify any privacy invasions [7].
- With the advent of information technology, the tension between evaluative surveillance and privacy rights intensifies. Transparency regarding surveillance methods and the explicit consent of employees are crucial for ethical monitoring practices [8].
- Legal aspects of employee surveillance through smart systems emphasize the necessity of balancing monitoring practices with respect for employees' fundamental rights, such as privacy and freedom of communication. Employers must adhere to data protection and labor laws to ensure lawful surveillance [9].

These studies collectively indicate an evolving understanding of employee privacy rights amid technological advancements and digitalization. The emphasis is on creating a legal and ethical framework that balances organizational security needs with protecting individual privacy rights and the importance of developing monitoring practices that respect employees' privacy rights while ensuring organizational security.

3 Methodology

Research Design

This study is based mainly on the authors' observations, which consist of more than 40 years of combined experience and good practice. The research design for this study involved a comprehensive literature review and in-depth case studies. The literature review established a theoretical foundation by examining existing research on cybersecurity surveillance, data protection, and privacy rights. Selection criteria focused on recent articles, books, and reports emphasizing ethical considerations, using databases such as Springer, Elsevier, JSTOR, and IEEE Xplore to ensure relevance. The case studies analyzed the practical applications and implications of cybersecurity surveillance measures in ten organizations selected through purposive sampling. These organizations, spanning industries such as finance, government, telecommunications, utilities, and production, were chosen for their advanced cybersecurity measures and privacy practices. Data collection involved document analysis, observation, and structured interviews with key personnel responsible for cybersecurity and privacy.

Research Hypothesis

Research hypothesis No. 1.: Increased Sources of Security Information Reduce Environmental Entropy: This hypothesis posits that having more sources of

security-relevant information decreases the unpredictability (entropy) of the security environment, leading to more effective threat detection and mitigation.

Research hypothesis No. 2.: **Effective Security Monitoring Requires Access to Personal Data**: This hypothesis explores whether security measures can be effective without infringing on employee privacy by accessing personal data.

Theoretical basis of the affected domains

Difference between cyber security and information security.

Information security is a state in which the information is considered resilient and safeguarded against identified risks. It is a part of information management, regardless of the data's physical state, format, how it is interpreted, and the medium through which it is stored and transmitted. According to ISO/IEC 27000:2018, 3.28, **information security is the preservation of confidentiality, integrity, and availability of information** [10]. In addition, other properties, such as authenticity, accountability, non-repudiation, and reliability, can also be involved.

According to ISO/IEC 27032:2012, 4.20, **cybersecurity is the preservation of confidentiality, integrity, and availability of information in Cyberspace** [11]. Although in the new version of ISO/IEC 27032:2023, 3.6 definition of cybersecurity was changed, it is still related to confidentiality, integrity, and availability by the following explanation: cybersecurity is the safeguarding of people, society, organizations, and nations from cyber risks [12]. According to ISO/IEC TS 27100:2020, 3.2: **Safeguarding means keeping cyber risk tolerable** [13]. This does not contradict the previous definition.

The point is that both types of security have the same goal—information protection. Except that "cyber" security only refers to information in the context of cyberspace (Fig. 1).

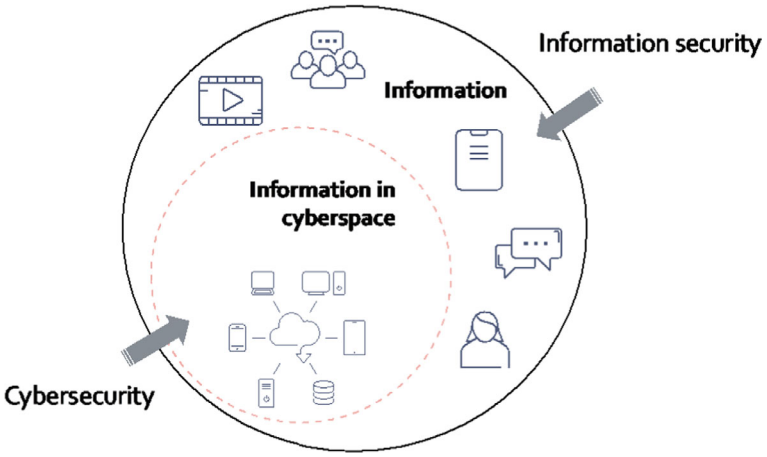

Fig. 1 The relationship between information and cyber security. *Source* Designed by the authors

If we were to express ourselves exactly, then "cyber security" is a subset of the set "information security" because all its elements are also elements of the set "information security". At the same time, the inverse of this statement does not hold.

The term "privacy" and its expressions from legal point of view.

The Universal Declaration of Human Rights partially consolidated the right to privacy itself, which declares that: "*No one shall be subject to arbitrariness interference with his privacy, family, home or correspondence, nor to attacks upon his honor and reputation. Everyone has the right to the protection of the law against drought interference or attacks.*" The declaration also defines privacy in the way, that: "*The right to privacy is universally recognized as an individual, staff right of philosophical and moral origins*" [14].

Monitoring the use of IT resources provided by the employee thus potentially creates the possibility of collecting data and metadata that may immanently interfere with the employees' privacy and thus exceed the actual original purpose of collecting this data, which should have been limited only to the supervision of the security of the operation of IT systems. The privacy should be also understood as "*the right to be let alone*" [15]. This statement must be seen in the context of leaving the freedom of the individual until he decides (consent) on the possibility of being interfered with. Under the term "consent", it is possible to perceive not only consent in the true sense of the word but also any other expression based on which the individual is aware that there might be an interference with privacy. This might be expressed as a contract or an employment relationship but also an expression reproved by the law, to which imperative legal norms, bind the legitimacy of the subsequent intervention to privacy. This might be also a case of monitoring the cyber threats by a private entity.

Other statements also speak, that "*privacy should be defined as the claim of an individual to determine what information about himself or herself should be known to others*" [16].

The presented opinion can be interpreted a way that the data subject should also be the primary entity that will decide on the processing of his personal data and their further fate. This process should not only include the possibility to actively intervene in the way personal data is handled but also the right to receive regular and sufficiently clear information about the scope of processed personal data and potential informational conclusions that may result from the combination of this personal data. This should also involve information, when such personal information is obtained, and what uses will be made of it by others.

Privacy concerning the employer's interest

Reaching the awareness of employees on their data processing is a certain form of preventive protection of the privacy, personality, and their personal data. The measures that should be implemented to meet these expectations are feasible within a comprehensive GDPR Compliance. **We believe that the fundamental essence of the way the rights should be protected is based on two aspects - the first is prevention, and the second is enforcement**. Prevention should mainly consist of preventing the violation of the subjects' rights. In the context of personal data protection, prevention should mainly be manifested by securing all organizational and

technical solutions in such a way that they are limited exclusively to the achievement of a legitimate goal and do not interfere with the rights of other subjects beyond the scope of this goal.

However, reaching the goals of prevention should be accompanied with active cooperation with data subjects. This involves increasing awareness about data processing and their subsequent combination. On the other hand, the second aspect is the enforceability. This should be based on an ex-post mechanism, which comes into place once the rights of the affected subjects are affected. In addition to the traditional mechanism of judicial protection (authoritative enforcement of rights), we can also talk about preventive mechanisms for alternative dispute resolution between the employee and the employer. This would be not only a flexible solution but also a means to protect the reputation, working environment, and integrity of the given employer. In addition, this mechanism can also be in line with the rights of data subjects [17].

The relationship between cybersecurity and privacy

Modus ponens, or "the mode that affirms," is a fundamental logic rule widely used in mathematical proofs, computer science algorithms, and philosophical arguments. It is a staple in classical logic and critical thinking, illustrating a straightforward yet powerful form of reasoning that helps establish conclusions based on conditional statements and their affirmations and a way of deriving a conclusion from two premises. The structure of modus ponens is as follows:

- First Premise (Conditional Statement): If P, then Q.
- Second Premise (Affirmation of the Antecedent): P.
- Conclusion (Affirmation of the Consequent): Therefore, Q.

Here, P represents an antecedent condition, and Q represents a consequent condition. Modus ponens asserts that if the first premise is true (If P, then Q) and the second premise confirms P, it logically follows that Q must also be true.

So, the **transferred relationship between privacy and cyber security can be described in the following logical statement** using the modus ponens rule:

- Ensuring basic human rights can be done by law enforcement through legislation and contracts,
- Ensuring the right to privacy must imply the security of personal data processing,
- The security of personal data processing necessarily means taking adequate technical and organizational measures (to preserve the confidentiality, integrity, and availability of information),
- Information security is the preservation of confidentiality, integrity, and availability of information [1],
- Cybersecurity is the preservation of confidentiality, integrity, and availability of information in Cyberspace [11].

Considering that data protection can only be achieved by preserving the confidentiality, integrity, and availability of information, **an objective guarantee of the right to privacy can only be achieved through cyber security measures**.

The right to privacy, enshrined in various international conventions and legal statutes, places individuals at the forefront of data protection efforts, emphasizing the importance of transparency, consent, and accountability in data processing.

In conclusion, the relationship between confidentiality, integrity, availability, and the right to privacy underscores the complex interplay between data security and individual autonomy.

4 Main Objectives for Cybersecurity Surveillance

Here are some common types of surveillance related to cybersecurity:

Risk management

Cybersecurity risk management is an ongoing process that requires commitment at all organizational levels. By integrating risk management into organizational culture and business processes, organizations can significantly reduce their exposure to cyber threats and safeguard their operations, reputation, and bottom line.

Regulatory compliance

Ensuring the organization complies with applicable laws and regulations, which vary by jurisdiction. Compliance with standards involves implementing specific security measures, regular audits, and sometimes, reporting breaches to authorities.

Protection of the value of information assets

The owners' typical main motivation is economic considerations, including the intention to avoid financial losses. Information assets have significant economic value in the digital economy. Incidents and non-compliance with laws can lead to substantial financial costs, including fines, legal fees, compensations, and the costs associated with responding to and recovering from security incidents.

Intellectual property protection

Several key considerations come into play when examining personal data protection in the context of intellectual property (IP) protection. These considerations reflect the intersection between safeguarding personal information and maintaining the rights associated with IP.

Customer Expectations

Consumers are increasingly aware of privacy issues and expect companies to protect their personal information. Companies that fail to protect personal data adequately may lose customers to competitors who prioritize data protection.

Building Trust and Reputation

Protecting information assets helps build trust with customers, clients, and partners. Companies seen as responsible stewards of information assets can enhance their reputation, differentiate themselves from competitors, and foster customer loyalty.

Innovation and Competitive Advantage

By using data responsibly and transparently, companies can offer innovative services and products that respect privacy, appealing to privacy-conscious consumers. Compliance with international data protection standards enables companies to operate across borders more easily. Likewise, companies that follow the rules on cross-border personal data transfer can access new markets and opportunities.

Enhancing Data Management

Monitoring information assets enhances data management by promoting minimization, accurate data keeping, and ensuring accuracy, consistency, and completeness. It helps establish policies for data retention, archival, and disposal, effectively managing data throughout its lifecycle. Automating backup and recovery ensures data availability and helps detect and correct dataset errors.

Corporate Social Responsibility

Many companies view protecting information assets as part of their social responsibility. Ethical business practices, including responsible data handling, contribute to positive social impact and align with broader corporate responsibility goals.

Ensuring of individual's right to privacy

Protecting personal data is essential for safeguarding individuals' privacy and dignity. Monitoring can ensure that individuals' data is used in a manner that respects their privacy and autonomy, including protecting the data from unauthorized access, misuse, or disclosure.

Security tools and mechanisms

Main categories of tools

This article does not propose an exhaustive categorization of security tools. It is also important to emphasize that many of the following categories of tools overlap due to similar or shared functionalities. Security tools and mechanisms by which the objectives described above in Chap. 4 are typically fulfilled:

Security Information and Event Management systems

SIEM systems are essential security platforms that provide real-time analysis of security alerts from applications and network hardware. They enhance cybersecurity by detecting, analyzing, and responding to threats. SIEM systems identify potential security incidents by aggregating and analyzing log data from various sources across an organization's IT environment.

Managed Detection and Response

Typically named MDR are advanced cybersecurity solutions that provide organizations with comprehensive security monitoring, threat detection, and response capabilities. MDR services are typically offered as a service by third-party security by integrating with an existing organization's security infrastructure.

Access Control and Management

Employers often use systems to control access to different parts of their IT infrastructure, ensuring that employees can only access the information necessary for their roles. This includes managing permissions and using multi-factor authentication of users.

Data leakage prevention systems

Sometimes referred to as „Data Loss Prevention," these are security tools and strategies designed to detect and prevent sensitive or critical information from being leaked or lost. This could involve tracking and controlling data access, use, and transfers and monitoring for unauthorized disclosure of sensitive information outside the organization's boundaries.

Content filtering systems

Blocking access to data sources known as malicious or unrelated to work can prevent exposure to security threats and reduce the risks of malware infections. These solutions are designed to restrict or control the content that users can access or view on a network. Content filtering can be applied to various forms of digital content, including websites, emails, and files, to prevent exposure to inappropriate, offensive, or malicious content.

Network Monitoring

Employers may use software to monitor network traffic and detect suspicious activities, such as unusual data flows or attempts to access restricted areas of the network. This can help identify potential threats early and mitigate them promptly.

Email Surveillance

Monitoring emails to prevent data leaks, phishing scams, and other malicious activities. This could involve scanning for sensitive information being sent out of the network or looking for signs of phishing emails being received.

Insider Threat Detection

Using analytics and monitoring tools to identify potentially malicious activities by employees or contractors who might misuse their access to harm the organization. This includes detecting unusual access patterns or data handling that could indicate a threat.

Endpoint Security

Monitoring and managing devices that connect to the organization's network, such as computers, smartphones, and tablets, to protect against malware, ransomware, and

other cyber threats. This can include installing security software, conducting regular scans, and applying patches and updates.

Compliance Assurance Systems

Compliance assurance systems are integral components within organizational frameworks, designed to ensure that companies adhere to legal requirements, industry standards, and internal policies.

User Behavior Analytics

These measures analyze user behavior to detect anomalies that could indicate cybersecurity threats. This includes monitoring for unusual login times, excessive downloading, or accessing sensitive data without authorization.

Governance, Risk Management, and Compliance systems

GRC systems are integrated frameworks and technological solutions that help organizations manage governance, risk management, and compliance with laws. They ensure IT operations, financial practices, and employee conduct align with business objectives, manage risks, comply with regulations, enable effective information sharing, improve reporting, and avoid wasteful overlaps.

Security auditing systems

These are specialized tools and frameworks used to evaluate and ensure the security posture of an organization's information systems. These systems systematically evaluate a company's information system's security by measuring how well it conforms to a set of established criteria.

Vulnerability assessment systems

Vulnerability Assessment Systems are tools designed to identify and prioritize weaknesses in an organization's information systems and networks. They help detect security issues before attackers exploit them. Regular assessments enable organizations to patch vulnerabilities, strengthen defenses, and reduce the risk of security breaches.

Analyzis of the use of security tools

Based on the chosen research methodology, we came to the following findings (Fig. 2).

The highest penetration of security tools typically concerns monitoring technical vulnerabilities. This means that the collected and evaluated data can preferably be non-personal data. Content monitoring, as such, is not performed in the majority of the sample. Only 63% of respondents admitted to using security tools with built-in AI functions (Fig. 3).

The analyzed sample shows the highest use of security tools in banking industry and the lowest use in public administration.

This research would deserve a more extensive effort on a more significant statistical sample.

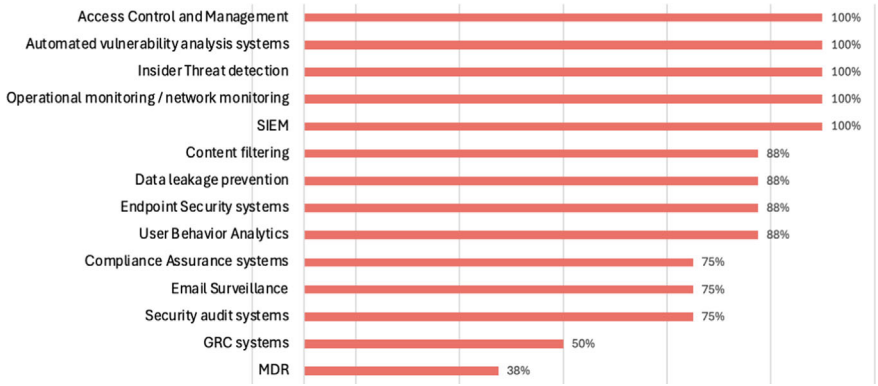

Fig. 2 Penetration of security tools

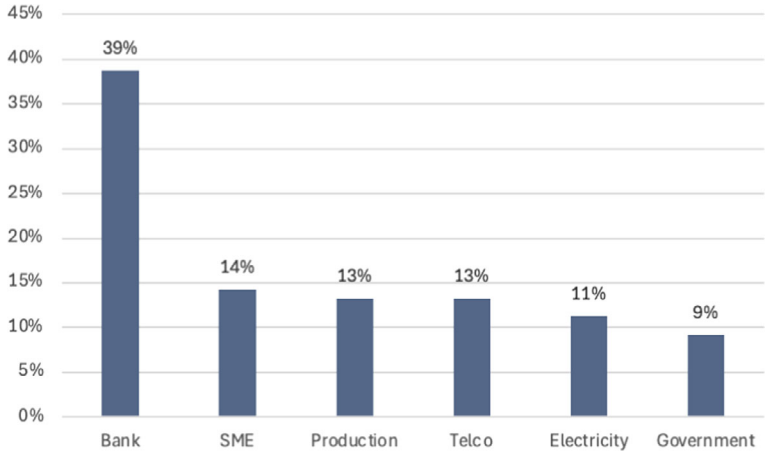

Fig. 3 Share of the use of security tools

5 Discussion

Privacy issues in different states of data

The so-called "DIKW model" [18] expresses a logical consequence of steps and stages between data, information, knowledge, and wisdom, with information being a contextualized „progression" of data as it obtains some meaning. Protecting privacy requires vigilance and proactive measures at every stage of the DIKW hierarchy to ensure that advancements in data analyzis and knowledge creation do not come at the expense of individuals' privacy rights. The following data states are discussed "only" in the context of data as digitized physical values**. The relationship between Data-in-Motion (DiM), Data-in-Use (DiU), Data-at-Rest (DaR), and Data-in-Cloud**

(DiC) and privacy is intricate. Each presents unique challenges and considerations for protecting personal and sensitive information. Understanding these concepts is crucial for implementing comprehensive privacy and data protection strategies. Here's how each relates to privacy:

Data-in-Motion (DiM): Dynamic, continuously generated, and processed data representing real-time information flow from various sources. The main privacy concern is **data interception during transmission**.

Data-in-use (DiU): Data characterized by its active engagement in computational processes, i.e., data actively accessed, processed, or analyzed in real-time operations. The primary privacy challenge is **unauthorized access and subsequent manipulation during processing**.

Data-at-Rest (DaR): Refers to data stored in persistent storage devices when not in use. This data state encompasses information archived, backed up, or otherwise retained. Personal data in this state are vulnerable to **unauthorized access and theft, particularly concerning portable media loss**.

Data-in-Cloud (DiC): Data storage and management in cloud environments. Privacy issues include **data breaches, unauthorized access, and lack of control over data locations**.

The relationship between the right to privacy and cybersecurity

So, what do cyber security, data protection, and the right to privacy have in common?

By default, processing by automated means occurs in cyberspace, so processing of any data (including personal data) occurs mostly in cyberspace. **Guaranteeing the security of personal data processing means adopting adequate technical and organizational measures**.

Cybersecurity ensures confidentiality, integrity, and the availability of information in cyberspace. From this statement, **personal data is protected through cybersecurity processes**. Surely, it is also impossible to leave out organizational measures, which are often also of the nature of legal documentation. This mediated relationship can be graphically displayed in an abstract form, as the next illustration shows (Fig. 4).

The GDPR only has general requirements for security measures; therefore, when specifying technical and organizational measures, **it is possible to start from the principle of analogia legis**. So, privacy protection means implementing measures and carrying out activities almost identical to those related to the security of any other type of information.

Data protection, explained correctly, should also be understood as "the protection of privacy" as such. This conclusion is because personal data, in its contextual form, represents a "statement about a person," including his/her behavior, private life, or even mental health issues, etc.

The legal essence of protection of employees' privacy, is built on the **basic premise of the conflict between the employer's interests and the personal, i.e., privacy interests of the employee**. This competition is based precisely on the

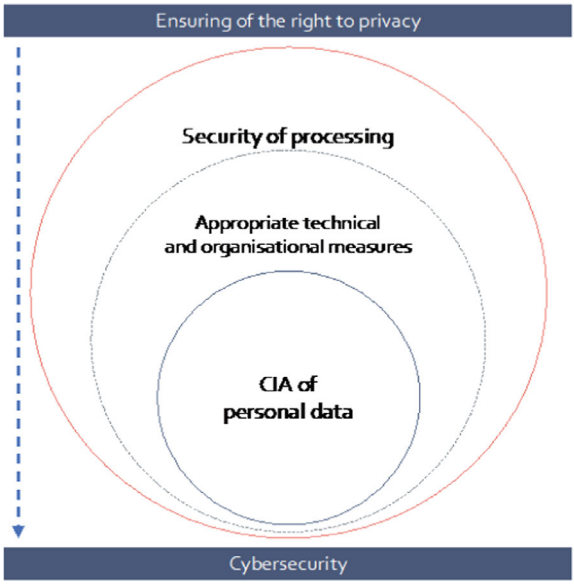

Fig. 4 Mediated relationship between privacy and cybersecurity. *Source* Designed by the authors

employers' interest in monitoring IT resources entrusted to the employee. In contrast, the employees' interest is in protecting his personal rights, i.e. privacy. We cannot perceive these rights of the employee only in the context of the processing of his personal data as such, but we must perceive it in a much broader context, which is the acquisition of information—in the form of comprehensive knowledge of some at least partial fact (wisdom state), which is related to the personality of the employee.

This can manifest itself in the form of obtaining information about the employee's private activities, character traits, and the purely private background of the employee. In other words, monitoring the use of all kinds of IT resources provided by the employer can lead to the production, subsequent acquisition, and creation of partial or even complex sets of information that can establish a certain personality profile of the employee as a private person. Such examples are the latter surveillance issues due to cybersecurity objectives.

Recital of the GDPR regulation point 67, referring to the conditions of automated processing of personal data, etc. states that: "*In automated information systems, the restriction of processing should in principle be ensured by technical means in such a way that personal data are not subject to further processing operations and cannot be changed*." The fact that the processing of personal data is limited should be clearly indicated. Therefore, if in the course of general monitoring carried out to protect against cyber threats, the personal data of employees is processed, so the employee should have the right to react effectively to this situation. As we state before in this article, the basis for achieving proper GDPR compliance is preventing **such an event that could interfere with the rights of an individual**. However, if these assumptions fail, the enforcement phase of the employees' rights should have started.

In this phase, we can include out-of-court resolution of employee rights interference. In this regard, the employee could react precisely by applying the provisions of the GDPR on the right to correction or the right to object to the processing of personal data. These principles are immanently based on limiting the processing of personal data [19]. The application of these rights by the data subject is thus only a reaction to the deviation from the principle of limiting the processing of personal data, which should apply as the primary principle in the processing process.

6 Conclusion

Proof of research hypothesis No. 1

The hypothesis that *Increased Sources of Security Information Reduce Environmental Entropy* posits that having more sources of security-relevant information decreases the unpredictability (entropy) of the security environment, leading to more effective threat detection and mitigation. In security, the premise is that the **environment's entropy is inversely proportional to the number of security-relevant sources of information**. This premise reflects an important concept in cybersecurity related to information management and threat analyzis. In this context, "entropy" refers to the amount of disorder or unpredictability in the system. This principle suggests that as the number of sources providing security-relevant information increases, the overall unpredictability or disorder within the security environment decreases.

High entropy (low number of information sources)

A low number of security-relevant information sources implies a lack of diverse perspectives and insights, hindering comprehensive security analysis and threat detection. **High entropy implies a state of higher uncertainty and less predictability in the security environment**.

This makes it more challenging to detect threats and vulnerabilities because less information is available to identify and understand potential risks. The system's state is more chaotic, making informed security decisions more difficult.

Low entropy (high number of information sources)

Conversely, when there are many sources of security-relevant information, the entropy or disorder in the environment decreases. **Low entropy indicates a more ordered system and higher predictability.** Each source contributes a piece of the puzzle, reducing uncertainty and making the behavior of potential threat actors more predictable. With comprehensive data from diverse sources, security systems can more accurately identify anomalies, predict attacks, and provide the chance for effective countermeasures implementation. The increased predictability and order also facilitate more effective security management.

Conclusion for research hypothesis No. 1

The statement that the **environment's entropy is inversely proportional to the number of security-relevant sources of information** suggests that more sources of information can lead to a more predictable and controlled security environment. In cybersecurity, "entropy" often refers to randomness or unpredictability within a system. A high-entropy environment is unpredictable and chaotic, making it difficult to secure, while a low-entropy environment is more predictable and ostensibly easier to manage.

This principle underscores the importance of integrating multiple sources of information in cybersecurity efforts. Organizations can reduce the entropy in their security environment by leveraging diverse data feeds, user activity records, patterns of access to resources, threat intelligence platforms, logs from various security devices, and inputs from human experts. This holistic approach enhances the ability to pre-emptively address threats, strengthening the security posture and creating a comprehensive view of the security landscape.

Cybersecurity and IT staff deploy various hardware and software tools to maintain confidentiality through appropriate security measures. Logically, such tools affect privacy.

Proof of research hypothesis No. 2

The hypothesis that *Effective Security Monitoring Requires Access to Personal Data* explores whether security measures can be effective without infringing on employee privacy by accessing personal data.

However, **the statement that "the security of information assets cannot be monitored and enforced without access to employees' personal data" is not entirely true**. While monitoring and enforcing the security of information assets may require some level of access to data, including potential data related to employee activities, this does not necessarily mean direct access to employees' personal data is always required.

As organizations navigate the complexities of data management and privacy protection, they must be aware of potential conflicts that may arise. Striking a balance between robust security measures and privacy considerations requires a nuanced approach considering legal frameworks, ethical guidelines, and societal expectations regarding data processing practices. Many employees use electronic communication tools, such as email and the Internet, as part of their free time activities. Some employers permit using these tools for staff reasons to some degree. This phenomenon might even increase the risk of encountering personal data i.e. during cybersecurity examinations and monitoring. Even if the permission for using the given tools for private purposes isn't explicitly granted, this might not exclude the employer from the later risk, nor from "giving up" on diligent complying with basic rules on processing the data that comes out from monitoring itself. The decisive factor in this kind of case is to act with the most professional care, which should be undertaken when handling potential personal data. This is even more stressed for the cases of employers who don't permit the private use of IT tools by their employees, but at the same time, they anticipate an this occasional use of these tools. However, when employers use monitoring to access the staff emails or internet usage, the possibility

of encountering the staff data increases rapidly. As mentioned, these monitoring practices bring employees' „privacy rights into direct conflict with employers' business interests". Moreover, the possibility of secret monitoring by employers only exacerbates this conflict [20].

Employer rights to information security

Employers have a **legitimate interest in securing their information assets** to protect proprietary data, trade secrets, and confidential information from unauthorized access or misuse. Robust information security mechanisms are essential for safeguarding data and preventing data breaches that could harm the organization. Employers' objectives for protecting information assets are described above in Chap. 4.

Under local or international regulations, **employers may also be legally obligated to protect certain types of information**, such as personal data, bank secrets, classified information, and data crucial for critical infrastructure operations.

Employees' right to privacy

Apart from assessing the necessity of a certain security surveillance system, **it is important to ask whether the intended processing is legitimate**. Answering these questions is crucial mainly because the employee and the employer have a specific contractual relationship. By default, the processing of personal data can be carried out on a contract as such. However, an employment contract is a special type of contract based on the unequal position between the counterparts. Potential monitoring activities of the employer are also associated with this position, which is carried out to protect the employer's IT systems. By default, **the usual monitoring of employees' performance of their duties or ensuring system security could be considered legitimate**.

In the same way, the interest in **monitoring employees' activities regarding the protection of information assets should also be considered legitimate**.

However, in practice, the opinion that the introduction and **use of information systems and technologies for the direct and principal purpose of monitoring employees' activity and behavior should not be permitted** [21].

In other words, processes that monitor employees' activities within IT systems and on assigned devices to detect activities corresponding to a breach of cybersecurity **should not be considered permissible if they use data collection that exceeds the necessary limit**. Such monitoring mechanisms are not legitimate means for employers to indicate suspicious activities.

The identification of suspicion should be the last link in the processes of automated monitoring of employee activities or IT systems and devices assigned to them. We are mainly talking here about the minimization of processing, higher restrictions in the processing and evaluation of data, and especially the establishment of intuitive mechanisms for recognizing the relevance of a given suspicion and its relationship to an actual security incident. This goal might be reached by duly customizing the SIEM use cases, used for monitoring. This conclusion is also supported by the GDPR itself, as it in principle speaks, that the proportionality must be considered by choosing methods that meet the employer's goals while having the most negligible impact on

employees' privacy. This approach should be consistent with the „privacy by design" and "privacy by default" principles outlined in the EU GDPR (Article 23).

Simultaneously, it's crucial to respect and consider the reasonable expectations of privacy in the workplace that employees naturally anticipate. These expectations are not only aligned with a specific social pattern' that individuals naturally expect but also serve as a well-established legal 'leading principle' applied for adopting court resolutions or imperative norms. Therefore, so-called "expectations" of the person should be threatened with adequate diligence, mainly when creating internal norms to comply with the data protection standards. The need for effective information security concerning employees' privacy rights requires organizations to establish clear policies, communicate transparently with employees about data collection and monitoring practices, and ensure that any data processing activities are compliant with relevant privacy laws.

Processing personal data for the protection of the assets

The goal of security measures is to protect the organization's information assets, and this can often be achieved through methods that respect employees' privacy and comply with data protection regulations.

Monitoring and safeguarding information assets effectively without infringing on personal privacy is often possible. There are a few key points that shall be considered from a cybersecurity point of view in the intention to increase the right to privacy and to protect the organization's information assets using surveillance at the same time:

Use of Non-Personal Data for Security: Many information security tools, such as intrusion detection systems, firewall monitoring, network traffic analyzis, etc., can be effectively operated without accessing personal data. These systems focus on indicators of compromise rather than personal details.

Least Privilege Principle: Security practices often follow the least privilege principle, granting access only to the information necessary for a specific purpose. This principle can minimize the need for access to information, which potentially includes personal data, unless it's directly relevant to the security task at hand.

Role-Based Access Controls (RBAC): Implementing RBAC ensures that only authorized personnel can access certain data or systems based on their organizational role. This helps protect sensitive information, including employees' personal data, from unnecessary exposure.

Use of Advanced Security Tools: Utilizing advanced security tools that leverage machine learning and AI can help detect threats based on patterns and anomalies without directly accessing personal content.

Data Minimization: Collecting the minimum amount of data necessary and anonymizing personal information where possible can help maintain security while respecting privacy and effectively implementing data protection principles, such as data minimization.

Anonymization and Pseudonymization: Techniques such as anonymization and pseudonymization can protect personal data while allowing for effective monitoring and analyzis. For example, analyzis of trends in network traffic or identifying suspicious behavior can often be done without knowing the specific identities of the individuals involved.

Network segmentation: Segmenting networks can limit the potential for unauthorized access to sensitive information, reducing the need for invasive monitoring.

Behavioral Analyzis: Focusing on behavioral patterns rather than personal details. For instance, detecting anomalies in access patterns or file transfer behavior can alert to potential security issues without needing to know the specific content of the data.

Use of Privacy-Enhancing Technologies (PETs): PETs allow organizations to conduct data processing and analyzis in ways that minimize or eliminate the exposure of personal data, thereby supporting both security and privacy objectives.

Transparent Policies: Having clear, transparent policies about data collection and monitoring helps ensure that employees understand what data is being collected and why, which can help balance security needs with privacy rights.

Legal Compliance: Adhering to legal frameworks such as the GDPR in the EU, which mandates data protection impact assessments for any personal data processing that is likely to result in a high risk to individuals' rights and freedoms, ensures that any monitoring is transparent, necessary, and proportionate.

Conclusion for research hypothesis No. 2.

Technological advancements have significantly impacted privacy and data protection in the workplace. These developments necessarily robust data protection laws that adapt to new technological challenges. The employment relationship inherently offers employers some rights to monitor and control workers' activities to ensure organizational security and efficiency. An employment relationship implies, in a widely applied view, a relation of subordination or dependency [22]. Along with the technological revolution, work relations have been understood, more than ever, in terms of privacy relations [23]. Therefore, regardless of employment type, all workers have a right to privacy and data protection. This right must be balanced with the employer's legitimate interests and the broader rights of colleagues, clients etc.

The pervasive nature of data processing and monitoring in the workplace has heightened privacy expectations. The concept of "reasonable privacy expectations" is gaining prominence, reflecting the dynamic interplay between workers' privacy rights and employers' interests in a rapidly changing technological landscape.

Confidentiality, integrity, and availability form the cornerstone of information security, guiding organizations in protecting data from unauthorized access, ensuring data accuracy and consistency, and maintaining data accessibility when needed. However, these principles are not standalone; they are closely linked to the broader concept of privacy, which encompasses individuals' rights to control their personal information and determine how it is collected, used, and shared. At the heart of this

relationship lies the need to balance safeguarding sensitive data and respecting individuals' privacy rights. Confidentiality dictates that authorized parties only access data, minimizing the risk of unauthorized disclosure. Integrity mandates that data be accurate, complete, and unaltered, ensuring that information retains its reliability and trustworthiness. Availability emphasizes that data should be accessible and usable when needed, **enabling efficient security operations and decision-making**.

Organizations implementing rigorous security measures to safeguard sensitive data must navigate the ethical and legal landscape surrounding employees' right to privacy.

The relationship between employer rights to secure information assets and employees' right to privacy is fraught with challenges and considerations. **Employers must balance monitoring employee activities for security purposes and respecting individual privacy rights**. Additionally, using technologies such as employee monitoring software, biometric data collection systems, and geolocation tracking tools can raise ethical concerns regarding data privacy and employee autonomy.

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