Lecture Notes on Data Engineering
and Communications Technologies 213

Peter Štarchoň
Solomiia Fedushko
Katarína Gubíniová *Editors*

Data-Centric Business and Applications

Advancements in Information and Knowledge Management, Volume 1

Springer

Lecture Notes on Data Engineering and Communications Technologies

Volume 213

Series Editor

Fatos Xhafa, Technical University of Catalonia, Barcelona, Spain

The aim of the book series is to present cutting edge engineering approaches to data technologies and communications. It will publish latest advances on the engineering task of building and deploying distributed, scalable and reliable data infrastructures and communication systems.

The series will have a prominent applied focus on data technologies and communications with aim to promote the bridging from fundamental research on data science and networking to data engineering and communications that lead to industry products, business knowledge and standardisation.

Indexed by SCOPUS, INSPEC, EI Compendex.

All books published in the series are submitted for consideration in Web of Science.

Peter Štarchoň · Solomiia Fedushko ·
Katarína Gubíniová
Editors

Data-Centric Business and Applications

Advancements in Information and Knowledge Management, Volume 1

Springer

Editors
Peter Štarchoň
Faculty of Management
Comenius University Bratislava
Bratislava, Slovakia

Solomiia Fedushko
Faculty of Management
Comenius University Bratislava
Bratislava, Slovakia

Katarína Gubíniová
Faculty of Management
Comenius University Bratislava
Bratislava, Slovakia

ISSN 2367-4512 ISSN 2367-4520 (electronic)
Lecture Notes on Data Engineering and Communications Technologies
ISBN 978-3-031-62212-0 ISBN 978-3-031-62213-7 (eBook)
https://doi.org/10.1007/978-3-031-62213-7

© The Editor(s) (if applicable) and The Author(s), under exclusive license to Springer Nature Switzerland AG 2024

This work is subject to copyright. All rights are solely and exclusively licensed by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.
The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.
The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

If disposing of this product, please recycle the paper.

Preface

Data-Centric Business and Applications: Advancements in Information and Knowledge Management explores the transformative power of data in business operations, decision-making, and application development. It provides a nuanced understanding of the ongoing paradigm shift toward data-centric approaches.

The book delves into advanced information and knowledge management concepts, focusing on data governance, analytics, knowledge discovery, and artificial intelligence. It covers topics like data-centric business models, emerging technologies, and ethical considerations, with each chapter by experts.

In the first chapter, "Peculiarities of Professional Training of Informatics and Mathematics Teachers at Universities in Poland and Ukraine," Olha Yuzyk, Yurii Pelekh, Ihor Voitovych, Nataliia Pavlova, Iryna Briukhovetska, Pavlo Sirenko, and Mariia Yuzyk explore the unique aspects of training informatics and mathematics teachers at universities in Poland and Ukraine, shedding light on specific challenges and approaches within this field.

Jürgen Klausmann and Jozef Papula delve into the unique selling propositions of Small and Medium Enterprises (SMEs) and their impact on mitigating the effects of COVID-19 in this chapter, providing valuable insights into the challenges these enterprises face.

In the third chapter, "Improving the Recruitment Process in Multinational Organizations Using Robotic Process Automation and Artificial Intelligence" Lubica Bajzikova and Tetiana Smerdova contribute to the discourse on multinational organizations by exploring strategies for enhancing the recruitment process by integrating Robotic Process Automation (RPA) and Artificial Intelligence (AI).

Mykola Oliynyk, Olga Stadnyk, Lidiia Piskozub, Andriy Zachepa, and Oksana Mykytyuk critically examine the discourse surrounding the so-called Marian Reforms, questioning whether they are a historical myth or a proven fact based on contemporary research.

Irina Roddvik, Solomiia Fedushko, and Anatoli Bourmistrov, in the fifth chapter, "Deprivation of Control" and an Evolution of the Institution of Expatriates: A Case Study of Changing HQ Controls Over Subsidiaries in a Norwegian MNC Internationalization Process" present a case study on the evolution of expatriate institutions

within a Norwegian multinational corporation, exploring changes in headquarters' control over subsidiaries during internationalization.

Ľubomíra Strážovská, Branislav Borecký "Management in Family Business in the Slovak Republic" focus on family businesses in the Slovak Republic, offering insights into management practices within this unique organizational context.

The author of the seventh chapter, "Network Approach to Linguistic Pattern Analysis for User Gender Identification of Social Internet Services" employs a network approach to linguistic pattern analysis for user gender identification in social internet services in this chapter.

Enikő Korcsmáros, Erika Seres Huszárik, Silvia Tóbiás Kosár, Ladislav Mura, and Bence Csinger explore the impact of the COVID-19 pandemic on Small and Medium Enterprises (SMEs) in terms of customer-centric practices, focusing on Slovakia and Hungary.

In the ninth chapter, "Advancing Video Search Capabilities: Integrating Feedforward Neural Networks for Efficient Fragment-Based Retrieval" Nataliia Melnykova, Natalya Shakhovska, Petro Pobereiko, and Dariusz Cichoń advance video search capabilities by integrating Feedforward Neural Networks for efficient fragment-based retrieval.

In the tenth chapter, "Technologies for Electronic Document Management in the Enterprise," authored by Mykhaylo Pasichnyk, Hryhoriy Savchuk, Sana Strelbytska, Lesya Tkach, Volodymyr Patrytskyi, and Yurii Palekha, explores technologies for electronic document management in enterprise settings, offering insights into effective practices and technologies.

In the eleventh chapter, "In-Depth Examination of the Effective Use of Social Networks for Communication in United Territorial Communities: Navigating the Digital Landscape," conducts an in-depth examination of the effective use of social networks for communication in United Territorial Communities, guiding on navigating the digital landscape.

Sergiy Gnatyuk, Rat Berdibayev, Marek Aleksander, Viktoriia Sydorenko, Oksana Zhyharevych, and Artem Polozhentsev in the twelfth chapter "Software System for Cybersecurity Events Correlation and Incident Management in Critical Infrastructure" introduce a software system designed for correlating cybersecurity events and managing incidents within critical infrastructure.

In the thirteenth chapter, "Waste Management by Using Smart Technology Application" Igor Šarlina and Jaroslava Kniežová explore waste management through the application of smart technology, presenting innovative approaches for efficient waste management practices.

Alexander Neubaur in next chapter "Smart Energy Components—Foundation of a Decentralised Energy Supply" lays the foundation for a decentralized energy supply by exploring smart energy components, contributing to the vision of a sustainable and decentralized energy future.

Vojtech Kollár and Silvia Matúšová, in the sixteenth chapter, "The Concept of Smart Cities—An Accelerator of the Circular Economy" delve into the concept of smart cities, examining how they can serve as accelerators for the circular economy and promote sustainability.

In the next chapter, "The Relationship of Sustainable Project Management to Project Success—A Current Literature Review" Kilian Weih and Michal Greguš provide a current literature review on the relationship between sustainable project management practices and project success.

Taras Ustyianovych, in the eighteenth chapter, "Data Science for Social Climate Change Modelling: Emerging Technologies Review," focuses on Data Science applications for social climate change modeling, presenting an emerging technologies review within this domain.

Michal P. Przewlocki and Zuzana Stolicna, in the nineteenth chapter, "Examining the Impact of COVID-19 on Private Healthcare Providers: Elective Procedure Volumes and Consequences" examine the impact of COVID-19 on private healthcare providers, explicitly analyzing elective procedure volumes and their consequences.

In the twentieth chapter "Management of Small and Medium-Sized Enterprises During the COVID-19 Pandemic in the Slovak Republic" Management of Small and Medium-sized Enterprises during the COVID-19 Pandemic in the Slovak Republic.

In the last chapter, Ľubomíra Strážovská and Branislav Borecký focus on the management strategies adopted by Small and Medium-sized Enterprises (SMEs) during the COVID-19 pandemic in the Slovak Republic.

The book caters to various audiences, including researchers, practitioners, academicians, and business professionals, offering insights into the role of data in shaping the future of businesses and applications.

The editors would like to extend their sincere appreciation to the authors for their valuable contributions, which have helped establish a resource that is indispensable for the investigation and advancement of data-centric business and applications.

Companies face high risk and uncertainty, requiring sustainable solutions based on digital-influenced techniques. Research in structural management, using existing knowledge, technologies, and data, can significantly aid in this goal.

Bratislava, Slovakia

Peter Štarchoň
Solomiia Fedushko
Katarína Gubíniová

Contents

Peculiarities of Professional Training of Informatics and Mathematics Teachers at Universities in Poland and Ukraine 1
Olha Yuzyk, Yurii Pelekh, Ihor Voitovych, Nataliia Pavlova, Iryna Briukhovetska, Pavlo Sirenko, and Mariia Yuzyk

The Unique Selling Propositions of Small and Medium Enterprises and Their Influence on the Level of Covid 19 Impact on These SMEs ... 15
Jürgen Klausmann and Jozef Papula

Improving the Recruitment Process in Multinational Organizations Using Robotic Process Automation and Artificial Intelligence 29
Lubica Bajzikova and Tetiana Smerdova

Historiographical Myth or Proven Fact? The Discourse Around the So-Called Marian Reforms in the Works of Contemporary Researchers 61
Mykola Oliynyk, Olga Stadnyk, Lidiia Piskozub, Andriy Zachepa, and Oksana Mykytyuk

"Deprivation of Control" and an Evolution of the Institution of Expatriates: A Case Study of Changing HQ Controls Over Subsidiaries in a Norwegian MNC Internationalization Process 87
Irina Roddvik, Solomiia Fedushko, and Anatoli Bourmistrov

Management in Family Business in the Slovak Republic 119
Ľubomíra Strážovská and Branislav Borecký

Network Approach to Linguistic Pattern Analysis for User Gender Identification of Social Internet Services 141
Solomiia Fedushko

The Impact of the Coronavirus Pandemic on SMEs in Term of Customer Centricity in Slovakia and Hungary 163
Enikő Korcsmáros, Erika Seres Huszárik, Silvia Tóbiás Kosár, Ladislav Mura, and Bence Csinger

Advancing Video Search Capabilities: Integrating Feedforward Neural Networks for Efficient Fragment-Based Retrieval 181
Nataliia Melnykova, Natalya Shakhovska, Petro Pobereiko, and Dariusz Cichoń

Technologies for Electronic Document Management in the Enterprise 199
Mykhaylo Pasichnyk, Hryhoriy Savchuk, Sana Strelbytska, Lesya Tkach, Volodymyr Patrytskyi, and Yurii Palekha

In-Depth Examination of the Effective Use of Social Networks for Communication in United Territorial Communities: Navigating the Digital Landscape 225
Vitalina Horova, Zoriana Sverdlyk, Yuriy Syerov, and Liliya Lesyk

Software System for Cybersecurity Events Correlation and Incident Management in Critical Infrastructure 247
Sergiy Gnatyuk, Rat Berdibayev, Marek Aleksander, Viktoriia Sydorenko, Oksana Zhyharevych, and Artem Polozhentsev

Waste Management by Using Smart Technology Application 271
Igor Šarlina and Jaroslava Kniežová

Smart Energy Components—Foundation of a Decentralised Energy Supply 293
Alexander Neubaur

The Concept of Smart Cities—An Accelerator of the Circular Economy 315
Vojtech Kollár and Silvia Matúšová

The Relationship of Sustainable Project Management to Project Success—A Current Literature Review 347
Kilian Weih and Michal Greguš

Data Science for Social Climate Change Modelling: Emerging Technologies Review 361
Taras Ustyianovych

Examining the Impact of COVID-19 on Private Healthcare Providers: Elective Procedure Volumes and Consequences 379
Michal P. Przewlocki and Zuzana Stolicna

Management of Small and Medium-Sized Enterprises During the COVID-19 Pandemic in the Slovak Republic 397
Ľubomíra Strážovská and Branislav Borecký

Peculiarities of Professional Training of Informatics and Mathematics Teachers at Universities in Poland and Ukraine

Olha Yuzyk, Yurii Pelekh, Ihor Voitovych, Nataliia Pavlova, Iryna Briukhovetska, Pavlo Sirenko, and Mariia Yuzyk

Abstract The article analyzes the professional standards of training of informatics and mathematics teachers in Poland and Ukraine and conducts a thorough analysis of the results of a survey of education seekers in Poland and Ukraine in areas of professional training. The survey was conducted in 2019/2020 in the following institutions of higher education of Ukraine—Kamianets-Podilskyi National University named after Ivan Ohienko, Rivne State Pedagogical University, Ternopil State Pedagogical University named after Volodymyr Hnatyuk. Students of the IV course of full-time education for the educational and qualification level "bachelor" of the educational program 014.09 Secondary education (mathematics, informatics), 014 Secondary education specialization 014.04 "Mathematics" with additional specialization "Informatics" and students studying under a shortened term of study were involved., who

O. Yuzyk (✉) · Y. Pelekh · I. Voitovych · N. Pavlova
Rivne State University of the Humanities, S. Bandera Street, 12, Rivne, Ukraine
e-mail: olichkajuzuk@ukr.net

Y. Pelekh
e-mail: ypelekh@ur.edu.pl

I. Voitovych
e-mail: ihor.voitovych@rshu.edu.ua

N. Pavlova
e-mail: nataliia.pavlova@rshu.edu.ua

Y. Pelekh
University of Rzeszów, Ks. Jalowego Street, 24, Rzeszow, Poland

I. Briukhovetska
Drohobych Ivan Franko State Pedagogical University, St. Ivan Franko, 24, Drohobych, Ukraine
e-mail: irynabruhovecki@gmail.com

P. Sirenko
Latvian Academy of Sport Education, Brivibas Gatve 333 Riga, Riga 1006, Latvia
e-mail: pavlo.sirenko@lspa.lv

M. Yuzyk
University of Warsaw, Szturmowa 1/3, 02-678 Warszawa, Poland
e-mail: mariayuzyk1@ukr.net

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2024

P. Štarchoň et al. (eds.), *Data-Centric Business and Applications*, Lecture Notes on Data Engineering and Communications Technologies 213,
https://doi.org/10.1007/978-3-031-62213-7_1

entered the second or third year based on the educational and qualification level junior specialist. In Poland, students from Cardinal Stefan Wyszenski University in Warsaw and Maria Curie-Skłodowska University in Lublin were responsible for full-time education, majoring in "Mathematics" and "Informatics for Teachers". The answers were concentrated around the following questions: "What guided you when choosing a profession (choose. There may be several of your decisions)"; "Choose the types of additional scholarships for higher education students that, in your opinion, will contribute to encouraging learning and mastering new knowledge and practices" and "Which subjects would you add to the list of those to be studied in higher education to obtain the specialty of "informatics teacher". The survey was conducted through Google-forms. The results of the study revealed discrepancies in the answers, caused, according to the authors, by the following factors: Poland's entry into the European Union and the establishment of educational programs in accordance with European standards of bachelor's training; foresight and the need to study new and promising disciplines related to computer science teaching methods, didactics, entrepreneurship, logic in computer science, programming, able to write projects with the aim of obtaining grants from the European Union.

Keywords Professional standards · Training of informatics and mathematics teachers · Higher education · European integration · Online survey · Legislative framework

1 Introduction

Transformations taking place in the education system of Ukraine in accordance with national and civilizational priorities cause new approaches to improving the content of the training of future computer science and mathematics teachers. These approaches are related to various aspects, first of all, the modernization of the school: the transition to the implementation of the Concept of the New Ukrainian School, support for the humanization of education, the ideas of child-centrism in education, the introduction of principles of competence and personality-oriented approaches in education of schoolchildren.

The Ministry of Education and Science of Ukraine is taking confident steps towards the European integration of education. This is evidenced by the following regulatory and legal documents: the Constitution of Ukraine, the Laws of Ukraine "On Education", "On Higher Education", "On Scientific and Scientific-Technical Activity", Decree of the President of Ukraine "On the Goals of Sustainable Development of Ukraine for the Period Until 2030" (from September 30, 2019 No. 722/2019). An important document is the "Strategy for the Development of Higher Education for 2021–2031", which was developed in accordance with the Decree of the President of Ukraine "On the Improvement of Higher Education in Ukraine" (dated July 3, 2020 No. 210/2020) and the relevant instructions of the Prime Minister of Ukraine (No.

23502/2/1-20 dated 12.06.2020 and No. 23502/3/1-20 dated 13.06.2020) (Strategy for the development of higher education for 2021–2031 roky (2020), p. 3).

It offers a diagram of the relationship between strategic goals and problems of the development of higher education in Ukraine. One of the problems is indicated in the strategy of higher education of Ukraine—"weak integration of higher education of Ukraine into the world and European educational and scientific space." Therefore, one of the strategies is important—"strategic goal 7. Integration into the European and world educational space taking into account national interests" [14].

V. Andrushchenko, L. Zagoruyko, V. Tsypko, V. Kuchai, O. Yuzik worked out the issue of the integration pedagogical values of Europe, the implementation of the right to education in the countries of the European Union, educational innovations within the framework of the Bologna Process [1, 19]. The state reform of educational services in the Republic of Poland was studied: the essence and criteria of the quality of education in Poland; structure of management and financing of personnel training; alternative education in Poland [16]. The theoretical and methodological principles of computer science teacher training in Poland in the second half of the 20th and the beginning of the twenty-first century were studied by Yuzyk [20]; the quality of higher education in Ukraine and Poland was studied by scientists [17]. The differences between manual and mechanized information processing were studied by A. Kuzminskyi, O. Bida, O. Kuchai and others in the article "Information Support of Educationalists as an Important Function of a Postgraduate Education System" [7]. Peculiarities of the organization and training of teachers of technical subjects and informatics in Poland were studied by Barskyi [2], Monko [10]. Yu determined the value-meaning concept of professional training for the future teacher [12].

There are studies that concern the organization of the educational process. For example, scientists Mishchenko O. and others study the cognitive independence of higher education graduates [8] The comparative characteristics of the functional state of future art teachers and students of other pedagogical specialties are described by scientists Kozin, O., Kretu, M., Boychuk, Yu., Kozina, Z., Korobeynik, V., and Sirenko, P. They indicate that "students—future teachers of creative specialties (faculty of arts) have more stability of the nervous system and less mobility in combination with the predominance of the parasympathetic department of the autonomic nervous system. That is why endurance exercises that do not require frequent switching of attention are suitable for them. Such exercises include walking, slow running, swimming. Exercises should be performed for at least one hour. They will also be suitable for exercises with the activation of visual perception references" [5]. We believe that computer science teachers are mostly sedentary too, especially when learning different programming programs, so the recommendations are important and can be taken into account.

O. Yuzyk, M. Yuzyk, L. Bilanych, V. Honcharuk, Bilanych H., Fabian M studied the organization of distance education in conditions of quarantine and military conflicts. In their opinion, it is important "we would like to raise the issue of the importance of organizational and educational-methodological support of distance learning in both secondary and higher education institutions of Ukraine" [18]. In their research, scientists Kocharian A. and Kovalova O. suggest using the NEO LMS

distance learning platform. "NEO LMS is a Web-platform created by the provider for its use in order to manage the educational process. The use of LMS of this type implies that the user receives the appropriate service from the provider according to the SaaS model of providing cloud services, which assumes that the main functions of ensuring work and technical support rely on a specific provider" [4].

However, no studies would have conducted an analysis of surveys of future computer science and mathematics teachers in Ukraine and Poland, and monitored the relationship with the state standards of professional training of computer science and mathematics teachers in Poland and Ukraine.

2 Methodology

The purpose of this study is to analyze the legislative and normative educational base of higher education, which ensures the European integration processes of higher education in Ukraine; to study the standards of professional training of informatics and mathematics teachers in Ukraine and Poland; to analyze the answers of students who took part in the online survey and to identify differences in the organization of the educational process of future teachers of computer science and mathematics, who are studying to obtain the educational qualification level "bachelor" in HEI (hereinafter—higher education institutions) in Poland and Ukraine.

The research methodology is based on *the principles of historicism, science, objectivity, systematicity, and evidence. The principle of the unity of the logical and historical* characterizes the relationship between real social progress and its reflection in theoretical thinking and the educational process, obliges comprehensiveness, completeness of study and coverage. Each phenomenon must be considered from the point of view of how it originated, what stages it went through in its development, and what this thing has become now. The principle of Eurocentrism reflects the relationship between professional training of informatics and mathematics teachers in Poland and normative documents of the European Union. It also provides a logical entry into Ukrainian higher education institutions, which train informatics teachers, with state-level documents and strategies aimed at a European approach.

An online survey of future informatics and mathematics teachers of the two countries was purposefully conducted to better understand the introduction of recommendations in the organization of professional training of informatics teachers in Ukraine.

To achieve the set goals and solve certain research tasks, we used general scientific and specific methods: generalization and abstraction; deduction and induction—for posing a problem; analysis of scientific sources and publications—for the analysis of literature and research related to the study of the legislative framework of the professional training of informatics and mathematics teachers in Ukraine and Poland; analysis of an online questionnaire based on the author's method of surveying higher education applicants (the number of respondents from Poland is 19 people, and from Ukraine—17 people) created in Google Forms; statistical processing and comparison

of the results of the online survey in order to highlight the research results and clarify the essence of the content of training in higher education of future teachers of informatics and mathematics; abstract-logical—for theoretical generalization and conclusions based on the results of the study.

3 Research Results

The cooperation agreement between Poland and the European Union in 1991 committed Poland to activities aimed at reducing differences in the creation of norms and certification through the use of technical requirements and European suitability assessment procedures (European norm No. 45000, translated and adopted as PNE No. 45013—General criteria related to personal certification characteristics of a person). University graduates must meet PSKZ standards (Polish standards of professional qualifications). In addition to the requirement listed above (refers to the personal certification characteristics of a person), the standard of professional qualifications is considered as a norm of requirements for a certain level. This includes: a set of skills, knowledge, psychological characteristics of a person, necessary to perform the tasks defined by this profession [15]. European standards are also taken into account in the professional training of computer science teachers in Poland. In particular, the duration of training is 3 + 2, which means two-level training of a teacher of this specialization. A student studies for 3 years at a bachelor's degree, and then a 2-year master's degree to supplement his studies. The second option is 4 + 1: four years of undergraduate studies and one year of master's studies. Also, a number of requirements apply to university graduates: a) thorough subject knowledge related to the chosen field of study and subjects taught in schools; the ability to manage the learning process of students; understanding of the processes taking place in a modern school in relationships: students, teachers, family [10].

In Poland, every teacher must be ready to work with information technology. The standard of such training includes the following issues: ability to work with concepts (terminology), means (equipment), tools (programs) and methods of information technology (abbreviated IT); IT technologies as a component of mastery of the teacher's work; the role and use of IT in the field of teacher education; use of IT in planning and designing the learning environment, assessment of benefits and assessment of student achievements; aspects of humanitarian sciences, ethical and legal, social, related to access to information technology and its use.

In the training standards of computer science teachers in Poland, IT knowledge and skills are clearly prescribed: the teacher constantly works on enriching information competences (knowledge of algorithmic elements, programming and more advanced capabilities of operating systems, programs and other software. In particular:

(1) knows the basics of elementary informatics, as in the field: history, structure, field and its foundations. You can imagine the relationship of informatics and IT with other fields of science and learning;

(2) knows and applies advanced software capabilities for the purposes for which they were developed: editors, spreadsheets, database management systems;
(3) knows the selected classical algorithms, which are used, in particular, when performing mathematical calculations for searching and organizing data or information that stores them in the correct form, including verbal, graphic and intended for the computer [13].

In Ukraine, the training of specialists is organized on the basis of the Law of Ukraine "On Higher Education", the National Doctrine of the Development of Education in Ukraine (twenty-first century), the Regulation "On the Organization of the Educational Process in Higher Education Institutions", the Resolution of the Cabinet of Ministers of Ukraine "On the List of Areas in Which training of specialists in higher educational institutions according to the educational and qualification level of a bachelor".

A bachelor majoring in "Informatics" receives the qualification of "specialist in information technologies", with a generalized object of activity—information processing processes using algorithmic methods using computer technology; second level—teacher of informatics, specialty 014 Secondary education (Informatics) (educational level "Bachelor").

On the basis of the state standard for the training of informatics specialists, the aforementioned researchers single out the following competencies of future informatics teachers: information-system, operational-informatics, computer networks, programming competence. It is noteworthy that the formation of the listed competences should be considered through the prism of the disciplines related to this process, given the direct dependence of the quality of the teaching of the academic discipline on the quality of the teacher's competences [7]. Today puts forward fundamentally new requirements for the professional training of a qualified specialist in the IT field. As noted by Yu. Peleh and O. Yuzyk, to solve this problem, it is necessary to change the system of standards in the field of higher education in accordance with the new Law of Ukraine "On Higher Education" and to adapt to the requirements of a student of a general educational institution. In Poland, students of these areas study more professionally oriented subjects that are relevant at the moment and will be relevant for decades to come. The programs of higher education institutions provide for the study of the basics of entrepreneurship. This indicates that graduates will be able to open their own business [3, 6] after completing higher education. The position regarding the study of foreign languages is interesting. In Poland, students study the English language perfectly at the B2 level [11].

Direct analyzes of surveys of students—future computer science teachers in Poland and Ukraine have not been tracked in scientific research, but we believe that such experience is effective in science and the study of professional training of a future specialist. Students of specialty 014.09 "Secondary education (Informatics)", field of knowledge 01 "Education/Pedagogy", qualification "bachelor of secondary education, teacher of informatics" were involved in the survey in Ukraine.

The survey was conducted in 2019/2020. In the following institutions of higher education of Ukraine—Kamianets-Podilskyi National University named after Ivan

Ohienko, Rivne State Pedagogical University, Ternopil State Pedagogical University named after Volodymyr Hnatyuk. Students of the 4th year of full-time education at the educational and qualification level "Bachelor" were involved.

Respondents were asked nine questions with pre-suggested answers in Ukrainian (an analysis will be made later in the text) to a link that was created in—google form. Link to the google-form at: https://docs.google.com/forms/d/1EvoKfD0o49Fps6lYNvDF8_fHJFmqkkMWRqAl_RNbqYU/edit#responses.

Similar questions in Polish were created separately, also in Google form, and were offered to students of two institutions of higher education in Poland—Cardinal Stefan Wyszenski University in Warsaw and Maria Curie-Skłodowska University in Lublin. The link to the Google survey is as follows: https://docs.google.com/forms/d/1ljqSxUJJ6Y0q_Pp7z8aIaZJzipsKTuomKl5BakSm7gU/edit. The survey in Poland was carried out thanks to scientists from higher education institutions: in Warsaw—(Dr hab. Jerzy Cytowski, prof. UKSW, member of the UKSW Senate, UKWS professor at the Institute of Informatics) and in Lublin—(professor, doctor of habilitation Przemyslaw Matula).

It was stated in the questionnaire that the answers to the questions will be taken into account in the analysis of the state of training of informatics teachers in higher education institutions of Ukraine. Answers were anonymous to ensure their truthfulness.

The analysis of the answers of the students of the two states confirmed the following:

First, the number of respondents from Poland is 19, and from Ukraine—17.

The results of the first question "Indicate which educational program you are studying from the following:

(a) 014.09—Secondary education (informatics), fields of knowledge 01—Education;
(b) for a shortened period of study, who entered the second or third year based on the educational and qualification level of a junior specialist in the specialty 014.09—Secondary education (informatics) in the field of knowledge 01—Education
(c) 014.09—Secondary education (informatics, mathematics,) fields of knowledge 01—Education
(d) 014.09—Secondary education (mathematics, computer science) of the field of knowledge 01—Education;
(e) 014 "Secondary education" specialization 014.04 "Mathematics" additional specialization "informatics".

The answers were as follows: 8 people (47.1%) chose the answer option "e"—014 "Secondary education" specialization 014.04 "Mathematics" additional specialization "informatics"; 5 people (25.4%) chose the answer option "d"—014.09—Secondary education (mathematics, computer science) of the field of knowledge 01—Education and 4 people (23.5%) chose the answer option "b"—for a shortened period of study, who entered the second or third year based on the educational and qualification level of a junior specialist in the specialty 014.09—Secondary education (informatics) in the field of knowledge 01—Education.

In Poland, students answered the same question as follows: "Mathematics" was chosen by 18 people, or (94.7%) and 1 person (5.3%) chose the answer informatics (teacher) (in Poland they are called specialties differently).

Our next question was about motivation when choosing a profession and sounded like this: "What guided you when choosing a profession (choose. There may be several of your decisions)".

Students from Ukrainian institutions of higher education chose the following options:

(a) by chance—2 persons, or 11.8%; (b) earning prospects—0 people; (c) interested in this area—9 people (52.9%); (d) love for the profession—5 people, or 24.9%; (e) high prestige of the profession—1 person (5.9%); (f) took into account the educational institution based on proximity to the place of residence and convenient access to the place of education—3 people (17.6%); (g) family traditions—0 persons; (h) abilities to study mathematics, informatics, which were still manifested at school—6 people, or 35.3%; (i) love for the discipline "Informatics" while studying at school—3 people or 17.6%; (j) the desire to learn applied software for teaching students and the ability to work with them—1 person (5.9%); (k) own ambitions in this field of activity—1 person (5.9%); (l) own abilities in this profession—1 person (5.9%).

Students from Poland distributed their answers to the same question differently: 13 people each (68.4%) chose the answers based on their interest in this field and their own abilities in it. 9 people each (47.4%) chose the answers—the ability to study mathematics, informatics, which were still manifested at school, and the love for the discipline "Informatics" while studying at school. 7 people, or 36.8%, chose the answer "love for the profession"; The answer "own ambitions in this field of activity" was chosen by 5 people (26.3%), as opposed to 1 person (5.9%) in Ukraine. The answer "own abilities in this profession"—4 people (21.1%). Three students were motivated by the prospect of earning (15.8%). In Ukraine and in Poland, two students each chose a case (10.5%). In Ukraine, 3 people (17.6%) were motivated to consider a place of study based on proximity to their place of residence and convenient access to the place of study; in Poland, this indicator was lower—1 person (5.3%). It is interesting that in Poland 1 person (5.3%) chose the type of motivation—family traditions, in Ukraine the figure was 0 people. The answer options were not chosen, that is, 0 people in such directions as the desire to master applied software for teaching students, the ability to work with them, and the high prestige of the profession.

Answering the third question, "Choose the types of additional scholarships for higher education students, which, in your opinion, will contribute to encouraging learning and mastering new knowledge and practices", students from higher education institutions of Ukraine chose the following scholarships: internship abroad—41.2% of respondents; monetary award for scientific or organizational activity 23.5% of respondents; 17.6% each chose the answers "supporting student initiatives" and "scientific scholarship".

Polish students' answers to the same question differed from Ukrainian students' answers. In particular, Ukrainian students chose four categories, and students from Poland chose five categories of answers; more than 52.6% of students chose scientific

scholarships in Poland against 17.6% from Ukraine. The rate of internships abroad in Poland is significantly lower −21.1, in contrast to Ukrainian students—41.2%. This is explained by the fact that in the European Union, students are not surprised by the possibility of an internship abroad. In Ukraine, these processes are more difficult for computer science teachers in terms of the possibility of such an internship (before Covid-19 and the war). As the fifth indicator of additional students in Poland, students chose "Financial support of projects within the fund of the educational institution—10.5% of respondents. Scholarship in the field of youth initiatives is a very small indicator—5.3%".

The next question in the questionnaire concerns the analysis of disciplines studied by future computer science and mathematics teachers in the two countries. A question with the following content was proposed: "Which subjects would you add to the list of those to be studied in higher education institutions to obtain the specialty of informatics teacher?" (choose no more than 5). And such a list of academic disciplines was offered

(a) Electronic education
(b) Didactic computer programs
(c) Construction of the computer science curriculum
(d) Object-oriented programming (JavaScript)
(e) Methodical practice in informatics
(f) Image processing and multimedia
(g) Mathematical principles of computer graphics
(h) Logic in computer science
(i) Basics of entrepreneurship
(j) Internet applications
(k) Computer control and robotics
(l) Computer graphics of instrument and mobile structures
(m) Multimedia digital sound processing
(n) Programming games on mobile devices
(o) Writing projects for obtaining grants from the European Union
(p) Training of informatics teachers abroad
(q) Organization of distance learning of students in quarantine and emergency situations.

The students' answers also interested us because of their unexpected results. In Poland, students focused their attention on studying the possibilities of distance learning, so they would like to have the following disciplines: "Electronic education"—12 people (63.2%), "Didactic computer programs" and "Organization of distance learning of students in quarantine conditions and emergency situations" by 11 people or 57.9%. 7 people (36.8%) would like to study the discipline "Logic in Informatics". 5 people each (26.3%) chose each of the following disciplines: "Building a computer science curriculum", "Internet applications" and "Programming games on mobile devices". 4 people each (21.1%) chose each of such disciplines as "Building a computer science curriculum", "Object-oriented programming (JavaScript)". Three people each (15.8%) chose the discipline "Writing projects

for obtaining grants from the European Union" and "Computer graphics of instrument and mobile structures". 2 people each (10.5%) would like to study the following disciplines: "Fundamentals of entrepreneurship" and "Computer control and robotics".

The least popular disciplines in the selection (1 person or 5.3%) were the disciplines "Multimedia-digital sound processing" and "Training of computer science teachers abroad".

In Ukraine, the respondents' answers to the same question were as follows: firstly, according to the number of students who chose a discipline, the number of respondents per discipline from 0 to 7 (inclusive); secondly, the disciplines that were chosen the most were related to the methodology of teaching computer science and studying abroad (electronic and distance learning in Poland). The indicators are as follows: 7 people each (41.2%) would like to study such disciplines as "Training of informatics teachers abroad" and "Methodical practice in informatics". Six people (35.3%) chose the discipline to study "Object-oriented programming (JavaScript)". Five people each (29.4%) would like to study the following disciplines: "Building a computer science curriculum", "Fundamentals of entrepreneurship", "Programming games on mobile devices" and "Organization of distance learning of students in conditions of quarantine and emergency situations". Four people each (23.5%) expressed their desire and noted that they are interested in such disciplines as "Electronic education", "Didactic computer programs", "Image processing and multimedia", "Computer graphics of instrument and mobile structures", "Applications" Internet". Three people (17.6%) were interested in the discipline "Multimedia-digital sound processing". One person each (5.9%) noted the educational disciplines "Mathematical foundations of computer graphics" and "Logic in computer science". Not a single respondent chose the discipline "Writing projects for obtaining grants from the European Union".

4 Results and Discussions

The state standard of computer science teacher training in Ukraine and the Polish standard provide for a number of requirements for the competencies of future graduates. Such competencies are psychological and pedagogical knowledge, the ability to work with terminology, tools, equipment, tools and methods of information technology. The quality of the formation of competences is considered through the prism of studying disciplines by students. It is the student who is the determining person who understands the cycle of the educational process of mastering the specialty and is able to evaluate or suggest making corrections in the organization of the educational process of higher education.

We bring up for discussion the following questions, which are important in professional training: motivation of the entrant when choosing a profession; types of additional scholarships for students; the possibility to adjust study plans, if the choice of disciplines by students is taken into account.

The analysis of students' answers showed the ambiguity of views on solving the question. The issue of motivation in choosing a profession showed that the interest of Ukrainian and Polish students in this direction is stimulated (9 people from Ukraine and 13 people from Poland chose). Polish students also chose another motivation, which is determined by the ability to study mathematics, informatics, which also showed from school a love for "Informatics" and the prospect of earning. We did not have a single prospect of earning as a computer science teacher. It is interesting that in Poland own ambitions also gained many positions (5 people chose this item).

The next point of discussion is the types of additional scholarships. In Ukraine, the desire to complete an internship abroad was high—41.2%, and in Poland—21.1%. Ukrainian students are not against receiving a scientific scholarship and a scholarship for student initiatives. Polish students were more inclined to choose a scientific scholarship—52.6%. Polish students were less interested in internships abroad—21.1%.

Therefore, we believe that Ukrainian students should be given the opportunity to receive scientific scholarships, as is the case in Poland, and students hope for them.

The third indicator for discussion is the possibility to add educational disciplines for study: in Poland, students chose disciplines that reveal the essence of distance learning, didactics of learning and e-education. Disciplines related to "Training of teachers abroad" and "Methodology of computer science practice" were popular in Ukraine. Therefore, the question arises for discussion, why would Polish students want to study disciplines related to distance learning methods? Perhaps it is also related to greater requirements for sanitation and hygiene compliance with Covid-19? The discipline "Logic in computer science" was also popular among Poles (7 people). In Ukraine, we would like to add the programming discipline of JavaScript to be studied. Maybe even more programming hours should be added to the curriculum? Ukrainian students were interested in the following disciplines: "Building educational programs in informatics", "Fundamentals of entrepreneurship", "Programming on mobile devices" and "Organization of distance learning of students in conditions of quarantine and emergency situations".

5 Conclusion

In the process of research, we clarified the conceptual approach in the professional training of computer science teachers and mathematics teachers, which is determined by the Law of Ukraine "On Higher Education" and the Law of Ukraine "On Education", the provision "On the organization of the educational process in institutions of higher education", the National Development Doctrine education in Ukraine (XXI century). An important factor is the "Strategy for the development of higher education for 2021–2031".

The analysis of students' answers given in the study allows us to make a comparative projection on the professional training of informatics teachers in Ukraine in the context of those transformations in the higher education system that are urgently

needed today. Naturally, we have our own uniquely formed system of higher education and the structure of training specialists. But the parallel in the strategy and systematicity of the Polish approach is extremely unique for us.

Our research is not exhaustive. The prospects for further scientific developments can be seen in a more detailed comparison of the curricula of computer science teacher training in universities and private educational institutions in the Republic of Poland and Ukraine; active research of the peculiarities of studying at a university for the training of informatics teachers and the peculiarities of the work of an informatics teacher in Poland in schools, gymnasiums and lyceums.

References

1. Andrushchenko, V.: Intehratsiia tsinnostei: pedahohichnyi dosvid Yevropy. Stattia persha. Velyka Khartiia Universytetiv. Vyshcha osvita Ukrainy, vol. 1, pp. 5–8 (2013)
2. Barskyi, T.: Dydaktychni osnovy tekhnolohii pidhotovky vykladachiv tekhnichnykh dystsyplin (za materialamy tekhnichnoi osvity u Polshchi). Avtoref. dys. … d-ra ped..nauk: 13.00.04/ Instytut pedahohiky i psykholohii profesiinoi osvity APN Ukrainy. Kyiv. 43 s (1993)
3. Fedushko, S., Ustyianovych, T., Syerov, Y., Peracek, T.: User-engagement score and SLIs/ SLOs/SLAs measurements correlation of E-business projects through big data analysis. Appl. Sci. **10**(24), 9112 (2020). https://doi.org/10.3390/app10249112
4. Kocharian, A.B., Kovalova, O.A.: Vykorystannia NEO LMS dlia heimifikatsii publikatsiinoi diialnosti yunykh doslidnykiv. Informatsiini tekhnolohii i zasoby navchannia, Tom **91**(5), 7 (2022). https://doi.org/10.33407/itlt.v91i5.4978
5. Kozin, O., Cretu, M., Boychuk, Y., Kozina, Z., Korobeinik, V., Sirenko, P.: Comparative characteristics of the functional state of future art teachers and other pedagogical specialties students. Health Sport. Rehabil. **8**(4), 28 (2022). https://doi.org/10.34142/HSR.2022.08.04.02
6. Kryvinska, N., Strauss, C., Auer, L., Ivanochko, I.: Assessment of business value from services re-use on SOA-based e-business platform. In: Proceedings of the 12th International Conference on Information Integration and Web-Based Applications & Services (iiWAS '10). Association for Computing Machinery, New York, NY, USA, pp. 493–500 (2010). https://doi.org/10.1145/1967486.1967563
7. Kuzminskyi, A.I., Kuchai, O.V., Bida, O.A.: Vykorystannia polskoho dosvidu pidhotovky fakhivtsiv z informatyky v systemi pedahohichnoi osvity ukrainy. Informatsiini tekhnolohii i zasoby navchannia, Tom **68**(6), 206–217 (2018). http://www.irbis-nbuv.gov.ua/cgi-bin/irbis_nbuv/cgiirbis_64.exe?I21DBN=LINK&P21DBN=UJRN&Z21ID=&S21REF=10&S21CNR=20&S21STN=1&S21FMT=ASP_meta&C21COM=S&2_S21P03=FILA=&2_S21STR=ITZN_2018_68_6_18
8. Mishchenko, O., Smyrnova, T., Tkachenko, T., Potamoshnieva, O., Yuzyk, O., Berezhnyi, Y.: Conditions for activating the cognitive independence of higher education seekers. Int. J. Comput. Sci. Netw. Secur. **21**(10), 245–250 (2021). https://doi.org/10.22937/IJCSNS.2021.21.10.34
9. Monko, R.M.: Istorychnyi analiz stanovlennia systemy pidhotovky vchyteliv «tekhniky ta informatyky» v Respublitsi Polshchi. Naukovi zapysky Ternopilskoho natsionalnoho pedahohichnoho universytetu imeni Vasylia Stefanyka **3**, 385–390 (2011)
10. Monko, R.M.: Pidhotovka vchyteliv tekhniky ta informatyky na fakultetakh informatsiino-tekhnichnoho navchannia v Polshchi. Naukovi zapysky Ternopilskoho natsionalnoho pedahohichnoho universytetu imeni Volodymyra Hnatiuka **1**, 154–158 (2014)

11. Pelech, J., Juzyk, O.: Cechy przygotowania zawodowego nauczycieli informatyki w Polsc**e**. Naukovyi visnyk Mykolaivskoho natsionalnoho universytetu imeni V. O. Sukhomlynskoho. Pedahohichni nauky **1**, 248–254 (2018)
12. Pelekh, Y.V.: Tsinnisno-smyslovi kontseptsii profesiinoi pidhotovky maibutnoho pedahoha: monohrafiia/Yu.V. Pelykh; za red. M.Yevtukha. Rivne. 400 s (2009)
13. Standardy przygotowania nauczycieli w zakresie technologii informacyjnej i informatyki. (Dokument przygotowany przez Radę ds. Edukacji Informatycznej i Medialnej—sierpień), 15 s. http://www.math.uni.opole.pl/~ebryniarski/standardy_inf.pdf, c. 8 (2003)
14. Stratehiia rozvytku vyshchoi osvity na 2021–2031 roky (2020). K. 71 s. https://mon.gov.ua/storage/app/media/rizne/2020/09/25/rozvitku-vishchoi-osviti-v-ukraini-02-10-2020.pdf
15. Sysoieva, S.: Napriamy realizatsii standartiv profesiinykh kvalifikatsii: dosvid Respubliky Polshchi. Shliakh osvity **1**, 19–23, s. 19–21 (2008)
16. Vasyliuk, A.: Vyshcha osvita Polshchi: struktura, upravlinnia, finansuvannia, pidhotovka kadriv. Osvita i upravlinnia, Kyiv **2**, 154–163 (1998)
17. Yuzyk, O., Mazaikina, I., Bilanych, H., Yuzyk, M.: Quality of higher education in Ukraine and Poland: comparative aspects. Comp. Prof. Pedagog. **9**(1), 66–75 (2019). https://doi.org/10.2478/rpp-2019-0008
18. Yuzyk, O., Yuzyk, M., Bilanych, L., Honcharuk, V., Bilanych, H., Fabian, M.: Distance learning in higher education institutions in conditions of quarantine and military conflicts. IJCSNS Int. J. Comput. Sci. Netw. Secur. **22**(4), 747 (2022). https://doi.org/10.22937/IJCSNS.2022.22.4.87
19. Yuzyk, O.P.: Yakisna osvita – odna iz umov modernizatsii systemy osvity v Ukraini v ramkakh Bolonskoho protsesu/ Mater. XI Mizhnar. nauk.-metod. konf. «Zabezpechennia nastupnosti zmistu v systemi stupenevoi vyshchoi ta pisliadyplomnoi osvity». Nova pedahohichna dumka **1**, 50–53 (2013)
20. Yuzyk, O.P.: Teoretychni ta metodychni zasady pidhotovky vchytelia informatyky u Polshchi (druha polovyna XX—poch. XXI st.). 13.00.01—zahalna pedahohika ta istoriia pedahohiky. Dysertatsiia na zdobuttia naukovoho stupenia doktora ped..nauk. Rivnenskyi derzhavnyi humanitarnyi universytet. 2022, 622 s. https://www.rshu.edu.ua/images/afto/anons/uzik_op_disert.pdfne

The Unique Selling Propositions of Small and Medium Enterprises and Their Influence on the Level of Covid 19 Impact on These SMEs

Jürgen Klausmann and Jozef Papula

Abstract An online survey was conducted to explore the extent to which unique selling propositions are used as a strategic objective in SMEs strategies and the extent to which these USPs influence the level of Covid 19 impact of these SMEs. 72% of the participants (CEOs, CFOs, owners, presidents of mainly German and USA SMEs) named "develop or sharpen a USP" as one of their strategic goals but with varying intensity between small and medium companies. The most frequent named USPs were leaders in: technology, customer orientation, speed, flexibility, quality and innovation with a difference between small and medium companies. The amount of 29 categories and the high amount of combined USPs show that most SMEs develop specific individual USPs to differentiate themselves from their competitors. However, 53% of small and 34% of medium-sized enterprises still have the potential to improve their competitiveness and crisis resilience by developing a USP. A direct dependence of the level of the Covid 19 impact on the utility of a USP as a strategic goal was not demonstrated.

Keywords Unique Selling Proposition (USP) · Small and Medium Enterprises (SMEs) · Strategic management · Covid-19 impact · Competitive advantage · Online survey

J. Klausmann (✉) · J. Papula
Faculty of Management, Comenius University Bratislava, Odbojarov 10, 82005 Bratislava, Slovak Republic
e-mail: Klausmann2@uniba.sk

J. Papula
e-mail: jozef.papula@fm.uniba.sk

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2024

P. Štarchoň et al. (eds.), *Data-Centric Business and Applications*, Lecture Notes on Data Engineering and Communications Technologies 213,
https://doi.org/10.1007/978-3-031-62213-7_2

1 Introduction

1.1 Relevance

The European Commission [1] defined Small and Medium Enterprises (SMEs) as independently operating companies with less than 250 employees and less than 50 Mio € revenues or a balance sum below 43 Mio €. In 2017, more than 99% of all German companies were SMEs. They were responsible for 35% of the turnover of all German enterprises [2]. In 2018, EU-28 SMEs accounted for 99.8% of all firms in the non-financial business enterprise sector (NFBS). They generated 56.4 per cent of value added and were responsible for 66.6 per cent of employment in the NFBS [3].

Obviously, SMEs have great importance for the global economy. Nevertheless, they have long been neglected in terms of research regarding strategic management, strategic positioning, and crisis sensitivity [4]. This is particularly critical as SMEs are generally more susceptible to crises than large and public companies because they usually have fewer resources and less equity [5–8].

1.2 Goals and Objectives

In industry it is common knowledge that Strategic Management (SM) helps enterprises to be successful and since Porter [9, 10] it is understood that SM is to gain competitive advantage. Meanwhile more and more SMEs understand that strategic management is just as beneficial for them as for large firms and lack of SM knowledge can seriously affect the performance of SME [11, 12].

To gain deeper insight into the proportion of SMEs that define and implement a strategy, SMEs' strategic goals, their impact on market position and operating results, an online survey was conducted in 2020. As the Corona 19 pandemic had spread worldwide at that time, the survey was also used to examine the relationship between corporate strategy and the impact of the pandemic on SMEs [13].

In the following, we will examine to what extent and in what form the topic of unique selling proposition (USP) is pursued as a strategic goal in SMEs, assuming that a strong USP can help to achieve significant competitive advantage, and whether the use of a USP in SMEs minimized the impact of the pandemic on the SMEs performance. Therefore, for this article in particular the results of the questions on the topic of USP and level of Covid 19 impact were analyzed.

The concept of USP was developed as early as the 1940s by Reeves [14] as a marketing concept, has been constantly developed further and is used worldwide [15–17].

2 Theoretical and Conceptual Background

2.1 Method

Between July 3, 2020, and April 29, 2021, an online survey was conducted at https://www.umfrageonline.com. This survey should provide new insights into strategies and strategic goals of SMEs and their impact on their crisis resilience. Here, in particular, the answers to questions regarding company size (revenue and number of employees), company strategy and strategic goals (especially regarding the development and sharpening of a USP) and level of Covid 19 impact on SMEs performance were analysed.

Potential participants, decision makers of industrially active SMEs (managing directors, managing partners, owners, presidents, CEOs and CFOs), mainly in Germany and USA, were searched and selected mainly through the internet platform LinkedIn, https://www.linkedin.com. Then they were asked to network with the author's LinkedIn profile. Once the potential participants contacted had accepted the LinkedIn invitation, they were invited to participate in the survey by sending the survey link, https://www.umfrageonline.com/s/ba7fd95.

2.2 Number of Participants Generated

In the end, 109 out of 813 decision-makers contacted took part in the study, corresponding to a participation rate of 13% (see Table 1).

19 companies of the 109 participants did not fulfil totally the 2 criteria for SMEs, two firms had more than 250 employees, but their turnover was below 50 Mio €, 10 firms had revenues <50 Mio €, but had more than 250 employees, only seven firms exceeded both criteria for SMEs. For this reason, and because care was taken when selecting potential firms that they were independent companies (e.g. GmbHs in Germany) and not large or public companies, the responses of all 109 participants were considered for the following work. The list of the 813 contacted decision makers and their firms, including public available information is available.

Table 1 Number of contacted persons, generated participants, and their location

Location of participants	Number of contacted decision makers	Number of participants	Proportion
Germany	679	84	12%
Europe without Germany	48	7	15%
USA	82	18	21%
Rest of world	4	0	0
Total	813	109	13%

2.3 Meaningfulness of Generated Number of Participants

In 2018 in Germany the total population of manufacturing SMEs was 703,716 [2], the total population of SMEs in Europe was approximately 22 million SMEs at that time. That means that with 109 participants the confidence level of the results of the questionnaire for the total population is 98% with an allowable error rate of 10%.

3 Survey Results

3.1 Strategic Goal: Develop or Sharpen a USP

To find out whether participants have the strategic goal of developing or sharpening a USP, responses to question 14 were evaluated (does your strategy aim to develop a USP or sharpen the existing USP?).

Results:

72% (79) of the participants answered yes to above question; 22 participants answered no and eight did not answer this question. Based on these 79 participants of the study, it can be assumed that between 64 and 82% of all industrially active SMEs are pursuing the strategic goal of developing or sharpening an USP (confidence interval of five percent and assumption of a binomial distribution).

3.2 USPs of Participants

To gain a deeper insight into SMEs' USPs, the answers to survey question 15 were evaluated (what is your USP or what USP do you want to develop?).

The named and described USPs where listed, analysed and for further evaluation categorized. Due to the different and diverse USPs mentioned, 29 categories were necessary for the categorization.

Results:

66 of the participants gave insight in their USP and described it, whereas 41 did not name a USP. One of the 66 participants named "Market leader" as USP but to the author's understanding "Market leader" can be a result of an USP but is not an USP itself. 28 of the 66 participants described their USP as a combined USP of more than one singular USP (23 named two USPs, three named three USPs, and one each named four and five).

The number of 29 categories required for categorization and the high amount of USP combinations show that SMEs are developing specific, individual USPs to differentiate themselves from the competition.

To make the categorization comprehensible, the individual USPs mentioned are listed in the following Table 2.

U1: USP 1, etc.

C: Capacity; CM: Close to market; CC: Core competence; CT: Cost; CO: Customer orientation; F: Flexibility; I: Innovation; K: Knowledge; L: Local; M: Maintenance; OT: On time; PE: Personal relationship; P: Price; PR: Product; PP: Product portfolio; Q: Quality; R: Reliability; SE: Service; SS: Setting standards; SO: Single source; SM: SME; SR: Solution provider; SP: Specialist; S: Speed; SU: Sustainability; T: Technology; TB: The best; TK: Turnkey.

For further analysis, the 29 categories were evaluated.

Results:

Technology leadership (16%) was named most frequently, ahead of customer orientation (11%), speed (9%) and flexibility (8%), which are the USPs in which SMEs generally excel due to their size and original reason for founding. As expected, price leadership (2%) and cost leadership (2%) play a subordinate role for SMEs. Table 3 shows in detail the number and proportion of the USP categories of all named USPs.

Technology leadership in combination with another USP was also mentioned most frequently, followed by quality leadership, speed and flexibility, which means that technology leadership is the most frequent USP of SMEs and thus seems to be the greatest strength of SMEs compared to the other USPs used by SMEs.

Table 4 shows the USP combinations most frequently mentioned in conjunction with other USPs.

Furthermore, it is investigated whether there is a correlation between company size and the frequency of using USPs as a strategic goal. For this objective, the participating companies who named a USP were divided into small and medium enterprises, based on the number of employees:

Small enterprises: 0–50 employees

Medium enterprises: 51–250 employees.

Results:

Only 47% of small enterprises compared to 66% of medium enterprises named USPs. This indicates that strategy development and implementation, specifically regarding—development of a USP—depend still on the size of the company.

Furthermore, it is investigated whether there is a correlation between company size and type of USP.

Results:

Technology leadership and speed leadership are aspired to almost equally often by both types of company. In contrast, medium-sized companies are more likely to strive for customer orientation and quality leadership than small companies; small companies, on the other hand, are more likely to strive for flexibility leadership than medium-sized companies (see Table 5).

Table 2 Named USPs categorized in 29 categories

Named USP	U1	U2	U3	U4	U5
High delivery reliability with high quality	Q	R			
Velocity of the sale for the distribution business; Custom design to meet the client‘s requirements on the project business	S	CO			
Control of market access by setting de facto market standards	SS				
To be the quality market leader in the industry	Q				
A very high degree of flexibility in the planning and implementation of customer requirements	F				
Technology leader—setting quality standards in our field of activity	T	SS			
We position our company as a boutique firm and largely only take jobs that fit our core competencies and margin	SP	CC			
We aim to be the best auto body repair shop for insurance companies to refer their clients to for repairs	TB				
We help our customers reduce cost, help our customers grow their business and simplify their supply chain	CO				
To be the fastest	S				
Niche process and large-scale production	SP				
Timely deliveries of needed and disparate product line. Single source	OT	SO			
Scientifically based	K				
Service with unmatched product quality	Q	SE			
I have 35+ years of experience in my industry and know it very, very well. Also, I have made good relationships with many other good solutions providers.; We are an engineering consulting business—we solve ANY and ALL problems by working with clients directly and also engaging with other industry experts to bring the required knowledge and answers to clients	K				
Know-how and capacity to further develop and integrate the manufacturing steps of our main product	K	C			
This depends on the article group or application					
On the product side: modularity, easy installation and maintenance; On the market side: close proximity to the market	T	M	CM		
To create additional benefits for customers through customer-oriented consulting and services; We do not sell goods, we solve the customer’s problem	CO				
Products specially developed for plant series of our customers	CO				
Offer individualized customer solutions starting from small requirements	SR				
In the niches in which we move always be the fastest, most flexible and those who offer the most competitive price	S	F	P		
Industry 4.0	T				
Being best producer and customer oriented	TB	CO			

(continued)

Table 2 (continued)

Named USP	U1	U2	U3	U4	U5
High touch. We want our salespeople to have strong relationships with customers	CO				
Solution Maker and Turnkey	SR	TK			
Innovation leader	I				
Technical features that are far superior to the competition;—Consistent digitization and data storage to offer additional features;—Software as a product	T				
Hydrostatics	T				
Quick delivery	S				
Small to mid-sized OEMs are undeserved in the marketplace by large providers. We focused on changing the buying experience and locking in loyal customers. The result has been, no large concentration with any customer. We have grown to nearly 200 OEMs that use our product. By being open to producing specials and providing 3D models and application support at no charge, we have developed a loyal base. For example, although business is down dramatically due to COVID, we have added 40 new customers. When business reruns to normal we will surely grow again because of this effort	SP				
Use of new technologies for energy saving and IOT controls	T				
Highest flexibility paired with sustainability	F	SU			
In addition to the product and the associated further developments, the topic of corporate culture/service/stronger customer focus is also part of the differentiation. The unique selling propositions also come from intensive questioning of customers about benefits/further development and added value	SE	CO			
The path from product supplier to solution developer	SR				
UPS: Job exchange for the food industry in the German-speaking area	SP				
Modular system	T				
We are the first in the market to develop, manufacture and distribute automated ultrasonic deburring equipment	T				
Tried to sell customers on allowing us to build duplicate tooling for the four major markets, North America, Europe, South America and Asia. Currently they source separately and no opportunity to gain from lessons learned. This would help them lower their costs	SP				
A combination of 5 characteristics:—very high product competence (recognized specialists for our products);—complete product portfolio (for our product group);—uncompromising quality;—worldwide availability;—open cooperation, true partnership with customers	PR	PP	Q	W	CO
Our unique selling point is to be able to offer a contract manufacturing structure and in parallel a development structure to optimize the customer's design	SP				
Everything from a single source. With optimal service	PP	SE			

(continued)

Table 2 (continued)

Named USP	U1	U2	U3	U4	U5
Innovation and quality; Local manufacturer; SME and not a large corporation	I	Q	L	SM	
Product mix; And variety; Efficiency; Lean cost	PP	CT			
Ease-of-use, Data mining/process data utilization, cost performance	T	CT			
Production methods which no other competitors have!	T				
Special technology for more effective mechanical processing	T				
Technical advancement	T				
Flexibility and speed for individual customer solutions	F	S			
Develop innovative systems, independent of the "big players"—act more flexibly on and for the market	I	F			
Technological leadership	T				
Greatest possible flexibility with simultaneous reduction of the commissioning effort	F				
Technical status, innovations	T	I			
BIM-compatible planning. So far, only about 10% in Europe can do this; concentration on public administrations and hospitals or laboratories; flexible and very fast implementation of customer requirements	T	F			
Support already in the project planning and the communication with the customer. The customer must have the feeling that he has given his parts to his own factory for processing. In other words, the feel-good factor of the customer is in the foreground	CO				
Not only sales, but application and service—consulting; Innovative always new projects, around the core business	SE	I			
Speed	S				
Production of high-quality surgical instruments, custom-made products for medical technology, services in meeting regulatory and approval requirements	Q	SE			
Essentially in the service	SE				
Speed in implementing customer requests/projects based on decades of experience and over 37,500 formulations in a wide range of segments	S				
Very high quality, with faster delivery time	Q	S			
Technical leadership in the field of optical filters	T				
We want to provide our customers with all-round and, above all, personal advice. We shape the future of our customers together; the customer is the focus. His benefit is above all. And in doing so, we cultivate and emphasize personal contact in particular	CO	PE			

(continued)

Table 2 (continued)

Named USP	U1	U2	U3	U4	U5
Since I do not have my own product, but only mediate, I can only convey the characteristics by doing; be faster than others; always come up with new innovations; combine products and technologies that fit together or complement each other to give the customer additional benefits	S	I			
Flexibility, customer proximity, innovative, own product developments	F	I	CO		
Market leader in terms of price/performance	P				
	65	**28**	**5**	**2**	**1**

3.3 Dependency Between Developing a USP and Level of Covid 19 Pandemic Impact

To investigate if there is a dependency between developing or having a USP as a strategic goal and the impact of the Covid 19 pandemic the answers to question 15 (what is your USP or what USP do you want to develop?) and to question 21 (did your implemented strategy help minimize the impact of the Covid 19 crisis?) were evaluated by χ^2 test.

Definition:

Minimal Covid impact: question 21was answered with yes.

Strong Covid impact: question 21 was answered with no.

H0: There is no difference in the extent of Covid's impact on the companies studied that pursue the strategic goal of developing a USP and companies that do not pursue this strategic goal.

H1: Companies that pursue the strategic goal of developing a USP feel less impact from the Covid 19 pandemic than companies that do not pursue this goal.

Results:

With a $\chi^2 = 0{,}44$, tested at a significance level of $\propto = 0{,}05$, H0 must be accepted; this means that there is no significant dependence of the level of Covid impact on the utility of a USP as a strategic goal (see Table 6).

However, Klausmann and Papula [13] describe the extent to which a business strategy based on developing a USP, continuously improving competitiveness, and achieving a dominant market position minimizes the impact of Covid 19 and substantially increases SME resilience.

Table 3 Number and proportion of named USPs categorized in 29 categories

Named USPs	Number of named USPs	Proportion (%)	Cumulative proportion (%)
Technology	16	16	16
Customer orientation	11	11	27
Speed	9	9	36
Flexibility	8	8	44
Quality	7	7	51
Innovation	7	7	58
Specialist	6	6	64
Service	6	6	70
Knowledge	3	3	73
Solution provider	3	3	76
Product portfolio	3	3	79
Setting standards	2	2	81
The best	2	2	83
Cost	2	2	85
Price	2	2	87
On time	1	1	88
Product	1	1	89
Reliability	1	1	90
Core competences	1	1	91
Single source	1	1	92
Capacity	1	1	93
Maintenance	1	1	94
Turnkey	1	1	95
Sustainability	1	1	96
Personal relationship	1	1	97
Local	1	1	98
Close to market	1	1	99
Worldwide availability	1	1	99
SME	1	1	100
	101	100	

4 Conclusion

This paper aims to identify and document the essential USPs of SMEs and help practitioners to understand the importance of USPs for the success of SMEs.

79 (72%) of the participants (decision makers of SMEs) named—develop or sharpen an already existing USP—as one of their strategic goals. Therefore, it can

Table 4 Most used USP combinations

Technology leadership combined with	Quality leadership combined with	Leadership in speed combined with	Leadership in flexibility combined with
Setting standards	Reliability	Customer orientation	Sustainability
Maintenance	Service	Flexibility	Innovation
Cost leadership	Service	Innovation	Speed
Innovation	Speed		
Flexibility			

Table 5 Differences in number of USPs named between small and medium enterprises

Named USP	Small enterprise	Medium enterprise	Difference
Technology	12%	15%	3%
Customer orientation	5%	15%	10%
Speed	12%	10%	−2%
Flexibility	9%	4%	−5%
Quality	3%	9%	6%
Innovation	6%	6%	0
Specialist	5%	6%	1%
Service	5%	6%	1%

Table 6 Results of survey questions 15 and 21 summarized

Participants with	Minimal Covid impact	Strong Covid impact	Sum of participants
USP named	35	23	58
USP not named	15	14	29
	50	37	87

be assumed that between 64 and 82% of all industrially active SMEs pursue this strategic goal (confidence interval: 95%).

65 participants described their USP in detail and thereof 28 participants described their USP as a combined USP of more than one singular USP. The named USPs could be grouped and separated in 29 categories. The most frequent named USPs was leader in: technology (16%), followed by customer orientation (11%), speed (9%), flexibility (8%), quality (7%) and innovation (7%).

The amount of 29 categories and the high amount of combined USPs show that SMEs use the strategic goal of developing specific individual USPs intensively to differentiate themselves from their competitors, means to achieve a competitive advantage.

However, there are significant differences in the use of USPs between small (<50 employees) and medium-sized (51–250 employees) enterprises.

Technology leadership and speed leadership are aspired to almost equally often by small and medium enterprises while medium companies strive more for customer orientation and quality leadership than small companies. Small companies, on the other hand, strive more for flexibility leadership than medium-sized companies. That suggests that to strive for technology leadership is a major success factor for SMEs in our globalized world as other strong USPs as price and cost leadership are less achievable for SMEs in comparison to larger enterprises. Furthermore, our study shows that small companies have a lot of catching up to do when it comes to using a USP as a strategic goal compared to medium-sized companies.

And finally: As many as 53% of small and 34% of midsize companies could improve their profitability and their crisis resilience by incorporating the concept of developing a USP as a strategic goal in their corporate strategy [13, 18].

4.1 Further Research

Our recommendation for further research is to investigate whether a general guideline for SMEs practitioners for optimal use (define, develop, use) of USPs to achieve a competitive advantage can be developed. Furthermore, it is to be investigated whether a strong USP is the essential means to achieve a significant competitive advantage especially for SME in our global competitive world.

References

1. European Commission: Benutzerleitfaden zur Definition von KMU (2017). https://op.europa.eu/de/searchresults?p_p_id=portal2012searchExecutor_WAR_portal2012portlet_INSTANCE_q8EzsBteHybf&p_p_lifecycle=1&p_p_state=normal&queryText=Benutzerleitfaden+zur+Definition+von+KMU.&facet.collection=EULex%2CEUPub%2CEUDir%2CEUWebPage%2CEUSummariesOfLegislation&startRow=1&resultsPerPage=10&SEARCH_TYPE=SIMPLE. Accessed 06 Jan 2020
2. Institut für Mittelstandsforschung (IfM), Bonn: Kennzahlen der KMU nach Definition des IfM Bonn, Deutschland (2017). https://www.ifm-bonn.org/statistiken/mittelstand-im-ueberblick/#accordion=0&tab=0. Accessed 29 Oct 2019
3. European Commission: SME Performance Review. Annual Report on European SMEs 2018/2019 (2019). https://ec.europa.eu/growth/smes/business-friendly-environment/performance-review_en. Accessed 06 Jan 2020
4. Klausmann, J., Papula, J.: The strategic crisis as root cause for existence-threatening crises in small and medium enterprises. IAETSD J. Adv. Res. Appl. Sci. **VII**(III), 34–42 (2020)
5. Gunasekaran, A., Rai, B.K., Griffin, M.: Resilience and competitiveness of small and medium size enterprises: an empirical research. Int. J. Res. **49**(18), 5489–5509 (2011)
6. Hong, P., Huang, C., Li, B.: Crisis management for SMEs: insights from a multiple-case study. Int. J. Bus. Excell. **5**(5), 535–553 (2012)
7. Kraus, S., Moog, P., Schlepphorst, S., Raich, M.: Crisis and turnaround management in SMEs: a qualitative-empirical investigation of 30 companies. Int. J. Entrep. Ventur. **5**(4), 406–430 (2013)

8. Ozgulbas, N., Koyuncugil, A.S.: Risk classification of SMEs by early warning model based on data mining. World academy of science, engineering and technology. Int. J. Soc. Behav. Educ. Econ. Bus. Ind. Eng. **6**(10) (2012)
9. Porter, M.E.: Competitive Advantage: Creating and Sustaining Superior Performance. Free Press, 1230 Avenue of the Americas, New York, NY 10020 (1985)
10. Porter, M.E.: Competitive Strategy: Techniques for Analyzing Industries and Competitors. Free Press, 1230 Avenue of the Americas, New York, NY 10020 (1998)
11. David, F.R., David, F.R.: Strategic Management: A Competitive Advantage Approach Concepts and Cases. Pearson Education Limited, Edinburough Gate, Harlow, Essex CM20 JE, England (2017)
12. Stokes, D., Wilson, N.: Small Business Management and Entrepreneurship. Cengage Learning EMEA, Cheriton House, Noth Way, Andover, Hampshire, SP10 5BE, United Kingdom (2010)
13. Klausmann, J., Papula, J.: The level of Covid 19 impact dependent on the type of strategy implemented in small and medium enterprises. In: PEMF 2022, Conference Proceedings from International Scientific Conference "The Poprad Economic and Management Forum 2022", pp. 271–283 (2022)
14. Reeves, R.: Reality in Advertising, N.W. Widener Inc., 1105 Lexington Ave., New York NY10075 (2015)
15. Anderson, J.C, Narus, J.A., Van Rossum, W.: Customer value propositions in business markets. Harv. Bus. Rev. (2006)
16. Mayr, S., Mitter, C., Aixhmayr, A.: Corporate crisis and sustainable reorganization: evidence from bankrupt Austrian SMEs. J. Small Bus. Manag. **55**, 108–127 (2019)
17. Penzel, D., Kryvinska, N., Strauss, C.: Cloud market—analysis of potentials and challenges for service providers. In: AMCIS 2017 Workshops 4 (2017)
18. Klausmann, J., Papula, J.: The dependency of operating profit on strategic goals in small and medium enterprises. In: PEMF 2022, Conference Proceedings from International Scientific Conference "The Poprad Economic and Management Forum 2022", pp. 271–283 (2022)

Improving the Recruitment Process in Multinational Organizations Using Robotic Process Automation and Artificial Intelligence

Lubica Bajzikova and Tetiana Smerdova

Abstract In the ever-evolving business landscape, firms seek to improve efficiency and cut costs, often through workforce reduction and automation using technologies like Robotic Process Automation (RPA) and Artificial Intelligence (AI). This paper explores RPA and AI in-depth, discussing their significance, applications, and potential to replace human tasks. Artificial Intelligence covers a spectrum of intelligent machine behaviors, encompassing Fuzzy Logic, Neural Networks, and Robotics. It aims to create machines capable of human-like cognitive tasks, such as playing games and logical reasoning. RPA, on the other hand, automates business processes using computer programs with the capability to perform repetitive tasks typically done by human employees. The paper provides real-world examples of RPA and AI implementation in various sectors, including finance, telecommunications, and Human Resources, where automation can significantly streamline the recruitment process. Ethical and legal considerations, like GDPR compliance, are vital in these implementations. The paper concludes by emphasizing the potential for cost and time savings through automation while also suggesting using tools like Ansible and future enhancements like intelligent chatbots.

Keywords RPA · AI · Automation · Efficiency · Recruitment · Cost reduction · Implementation

L. Bajzikova (✉)
Univerzita Komenského V Bratislave, Šafárikovo Námestie 6814 99, Bratislava 1, P.O.BOX 440, Bratislava, Slovakia
e-mail: lubica.bajzikova@fm.uniba.sk

T. Smerdova
Lviv Polytechnic National University, 12 Bandera Street, Lviv 79000, Ukraine

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2024

P. Štarchoň et al. (eds.), *Data-Centric Business and Applications*, Lecture Notes on Data Engineering and Communications Technologies 213,
https://doi.org/10.1007/978-3-031-62213-7_3

1 Introduction

In the times of new technologies, methods of development, and willingness to be more efficient than competing companies, firms are looking for more advanced technologies. Despite their main goal, which is to have better results than their rivals in the market, they try to reduce costs by releasing some employees or replacing them with machines. Most people, when hearing that, are shocked and ask themselves if it is possible to do so, but here comes the answer, which is Robotic Process Automation (RPA) [1–3] and Artificial Intelligence (AI) [4]. Those two technologies are gaining popularity and being the most developed in the modern world. In the following paragraphs, those two methods will be explained in order to clarify their meaning, application, and spheres of life in which they could totally replace people.

1.1 Artificial Intelligence

Artificial Intelligence (AI) is intelligence demonstrated by machines or programs which has been previously implemented by programmers [5, 6]. In the domain of AI, we include Fuzzy Logic, Evolutionary algorithms, Neural Networks, Artificial life, and Robotics. It may also be taken into consideration as a part of Computer Science, which researches intelligence and simulation of behavior in made programs. The main purpose for its development is to create machines able to perform operations similar to the human mind and senses, like computer games, knowledge management, expert systems, and logical reasoning [7]. The first test concerning AI was held in the 1950s and is called the Touring Test. Its primary role was to carry out a speech between a human and a machine and check if a person was able to recognize whether a computer or another person made the responses. Also, at the same time, the first AI laboratories were created, and until today, they are the leading ones. During the delves, it turned out that the progress in that field of study is very slow and hard to discover, but on the other hand, some failures in this area were the beginning of new technologies useful for other purposes.

1.2 Robotic Process Automation

Robotic process automation (RPA) is an advanced technology of automatisation of business process models [8–10] with the use of computer programmes or robots which may operate using artificial intelligence in order to simulate human's work [11]. The main feature or advantage of that technology is performing operations which are normally made by employees [11]. The proper way of programming the robots allows the to accomplish operations with different difficulty level which main feature is their recurrence and limited number of exception [12]. RPA may be used in

every place where one robot can replace the process of integration of several systems. The main advantage is that robots do not need any workstations with physical interface because all their operations take place in virtual environment. Another worth mentioning feature is the ability to work between several systems without need to move so our invention may be called a virtual employee which proceeds the same process like a person to which it has been assigned before. The history of RPA begins with the first processes of automation [13]. Still, the breaking point was the evolution of programming and creating simple algorithms used for testing applications and catching the mistakes. It also allowed the employees to get better motivation for their work because properly written programme simplified the creation of documentation and allowed people to save their time, rise the efficiency and reduce amount of mistakes.

Lots of effort is put to develop those technologies and make them useful in every sphere of life but for now, their implementation is in the phase of testing and first projects are being introduced to our life to check their abilities whether they will be able to fulfill their role or no [14]. The aforementioned methods are considered as the future of development and alternative for people as employees [15, 16]. The machines may save lots of time because the virtual workers will not move when there will be a need to make some operation in another place opposite to employees who would have to change place and even go between the buildings to press only some key on the other computer.

2 Examples of Implementations

Although RPA&AI is relatively new topic, there are already some implementations in the real world.

2.1 Multinational Hospitality Company with PwC

Another example of implementation of Robotic Process with automation and Artificial Intelligence was done by a multinational company call **PwC** (also known as PricewaterhouseCoopers). It has a headquarters in United Kingdom and deals with all kind of professional services in fields such as Assurances, Taxes, Analytics and Financial Advisory. It estimates that 45% of the work activities can be automated, which would results in global saving worth around 2 trillion dollars [17].

One of their implementations concerned a multinational hospitality company, which possessed and managed huge variety of hotels and hostels around the whole world. Finance and Accounting department of this company wanted to reduce costs of all repetitive manual tasks performed daily by the employees. Second goal of this case was to create more automated activity reporting. The company PwC believes that an RPA can be used in Financial field to process various kind of documents

such as invoices, generate journal entries and for synchronization and integration of accounts.

Firstly their approach was to identify process that could be automated:

(a) Employees regularly rewrite data about revenue from one application to an Excel spreadsheet and another application simultaneously creating reports. This task was identified as relatively simple and tedious, but very time-consuming, consequently huge number of so called **FTE**s (**Full Time equivalent**) were associated with it, which resulted in lack of time for the rest of assignments, usually more important ones.
(b) Daily reporting that concerned cover information, which had to be feed into application, which on the other hand created out of it a daily journal, which should be send to defined list of emails.

Secondly, they have targeted exact processes yet to be automated to describe the problem above and created programs that fulfilled the requirements. Unfortunately, a technical description of solution is not available to public information. After the implementation they have measured they have measured feedback and listed results:

- After automatization of processes 5 FTEs were saved and a gain of 50–60% efficiently was obtained while performing the given tasks.
- Clients can now add more hotels/resorts to existing workbook in the Finance and Accounting Department.
- Further 50+ processes were identified as potentially optimizable.

(***PwC, N.D, Source***: https://www.pwc.be/en/documents/20171123-rethinking-retail-artificial-intelligence-and-robotic-process-automation.pdf).

2.2 Robotic Process Automation for Corporate Functions

The next example of utilization of RPA and AI instead of a Traditional Automation is the case of internal implementation of RPA program on key Corporate Functions, such as finance, compliance, treasury and marketing, in a company called Capgemini.

The main assumption of such a move is to reduce the time spent on performing tedious tasks and allow the workforce to perform more valuable assignments, consequently lowering the costs and susceptibility to errors. The illustration of an automated process can be seen in Fig. 1.

The main difference between the RPA and TA is the need of human interaction with the system during the process. Whereas in the latter category, the activities are still performed by people, only being aided by technology, in the first group the human activities are unnecessary since the decisions are made automatically. This therefore results in a much greater performance and mitigation of the human error.

Studies suggest that office workers on average spend up to 80% of their time at work performing repetitive tasks which could easily be "robotized". Delegating these chores to robots would liberate the employees to dedicate more time to operations

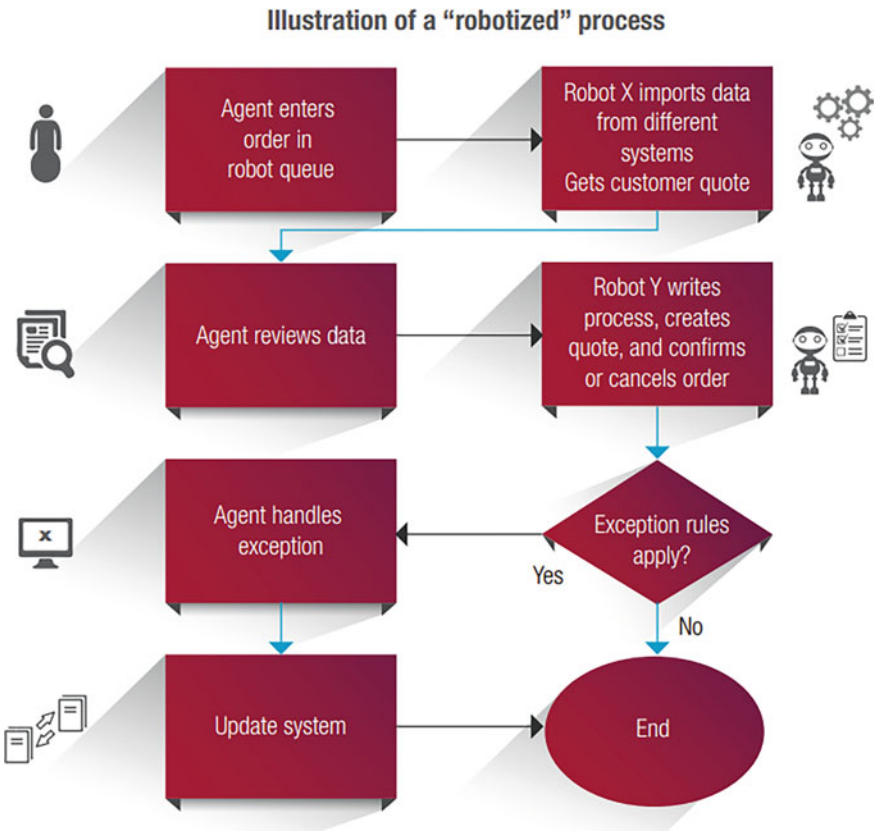


Fig. 1 Schema illustrating the process (https://www.capgemini.com/consulting-fr/wp-content/uploads/sites/31/2017/08/robotic_process_automation_the_next_revolution_of_corporate_functions_0.pdf)

involving creativity, judgement or soft skills, such as customer service. This in turn would result in increase of customer satisfaction.

Since its launch in 2014 the internal RPA program has automated over 200 processes on 50 robots in their delivery centers around the world. This caused the investment to pay back within just few months and in total decreased the running costs by 7 times. Those results however varied depending on the type of processes executed and seemed to have the highest effectiveness when a number of them could be run without interruption and on those not requiring human decisions In those best case scenarios, the cost reduction reached over 80%.

Finally, since the robots are able to operate continuously throughout the year, their total number of working hours in comparison with a standard employee is 8 times higher. What's more, the predictability of the operation of robots and their unconditional compliance to standards lead to easy record keeping of the activity's history, allowing for full transparency during audits [12].

2.3 UiPath—Finance and Banking

Robotic Process Automation and Artificial Intelligence can also be applied to financial services. Banking organization and institutions are already using intelligent software to lower the costs of hiring staff and paying them salaries. This solution saves valuable time, boosts the efficiency of company's prosperity and increases its profits. However, there are still some inconvenients concerning that topic.

In this situation UiPath company comes with the best solution offering an intuitive and crucial platform. It has many advantages such as:

- **Scalability**—multiple robots can work independently and on multiple machines. Moreover, they can connect to a single platform, anywhere from the whole world.
- **Reduced repeatability and redundancy**—no repeatable data entry tasks, best skilled employees focuses on high-value activities.
- **No paperwork**—platform provides tool for interpreting scans, transferring documents into computers, sending emails and detecting language to automate boring office work.
- **Untouched system**—robot does not affect the source code, it can be implemented with many desktop applications. This feature provides much faster automation of projects and lowers the expenses.
- **Data analysis**—robot can be applied to perform data analytics, create performance reports and identify transaction patterns.

Aforementioned features may be applied to many solutions in the banking area. Two of them Retail Credit Assessment and Retail Fraud detection will be described in the next paragraphs.

Retail Credit Assessment is a repeatable task which can be performed by UiPath robot [18]. This machine would check the income, expenses and many different financial aspects of the client. Then the analysis report would be created containing the creditworthiness.

Robot can also be applied to Retail Fraud Detection. Every banking organization is obliged to monitor the clients activities and find any suspicious actions. Gathering such information is a wearisome and time consuming process for employees. Robot can find retrieve all the data, find patterns and potentially suspicious activities. Then everything would be included into a report.

To sum up, UiPath solutions improve many different activities like: office work and data analysis. Its RPA platform is used widely in the world with successful results.

(***UiPath, N.D, Source***: https://www.uipath.com/rpa-in-banking).

2.4 Robotic Process Automation in the Telecom Industry

Another field in which Robotic Process Automation can be utilized is the Telecom sector. In modern world the need for being constantly connected with the globalized network is constantly increasing, and providers must compete with one another to provide the fastest, most affordable, and cutting edge services. The biggest problem is that most of them are slowed down with large amount of operational process such as administering data and costs.

Those problems are of the of such kind that could benefit significantly from use of the modern technology. With the process automation provided by RPA, telecom providers will be able to more easily manage their back office and deal with large volumes of repetitive and rules-based operational processes. The main focus could be centred on the customer experience, since their satisfaction is the main source of constant income.

But even the telecom industry right from the start has the nature that should be fitting the solutions suitable for automatic solutions, there are still problems impeding their implementations:

- **Low levels of operational agility**—the software layers used by the companies run simultaneously for support operation and their communication is very restricted and specific, making it hard for any possible modifications. Also many of them still require manual input, what absorbs a lot of resources, that could be spend on interaction with the clients.
- **Inefficient flow of information**—in telecom industry providers on a daily basis must manage a big amount of data, which includes documents for clients, workers and intermediary companies. Large amount of that is still in physical format and paperwork. Because of this inconsistency of used formats providers are unable to follow the course of their services.
- **High operating cost and capital expenditures**—telecom providers need to control the costs from multiple sources from maintaining data integrity and employees salary to software and hardware. Because of such high costs, not enough is spend on improving the customer satisfaction.

With investing into RPA, those problems could be solved and those factors could improve the work of the companies:

- **Higher levels agility and scalability**—RPA allows in the easy way to manage the software's workflow. By connecting it with the different departments, it could eliminate the need for manual input from the employees and let them focus more on satisfying customer needs.
- **Improved data communication and transmission**—RPA systems are non-invasive and could coexist with already used legacy systems. This would allow for removing the data gaps between different information sources and monitor them easily.

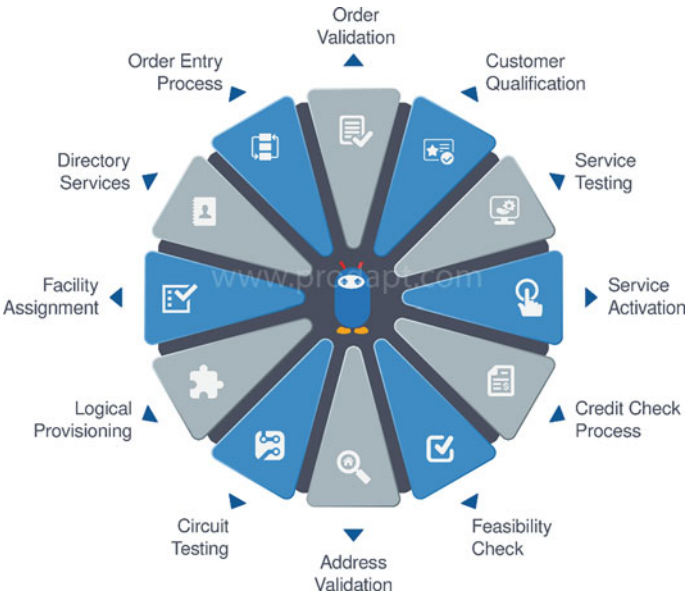


Fig. 2 Applications of RPA in telecom industries (http://www.prodapt.com/transforming-business-using-rpa/)

- **Significant cost reduction**—even though RPA requires investing the initial cost, later it is profitable in a long run with all its benefits allowing to focus on customer experience and making them stay with the current provider.

The applications of RPA that are planned to be implemented in telecommunication industry can be seen in Fig. 2.

The example of a company, which implemented Robotic Process Automation is AT&T, which trained over 2,000 employees to be able to create robots to automate the tedious, mind-numbing portions of their jobs. Those employees analyse data compiled from software bots. Starting from 2015 created were 1,000 software bots automating mundane, repetitive tasks for employees. They perform tasks ranging from helping technicians activate equipment for customers to aggregating data for service orders and customer service reports.

The result of the implementation of this system is not only that robots have taken the repetitive tasks from the workers, giving them the opportunity to focus on the more important jobs, but also bots are doing it much faster and more efficiently. Previously, employees spent hours aggregating this data every week and could only compile reports weekly. Now, they can see more data and make more insightful decisions.

In conclusion the telecom industry is the great field for introducing the Robotic Process Automation, because of the amount of repetitive jobs, that are necessary, but very simple. The other benefits of it would be higher levels agility and scalability, improved data communication and transmission and significant cost reduction [19].

3 Problem Description

In the times of modern development, changes in the world, and finding new branches of business [20], people started becoming mobile, changing their university courses, trying to study different subjects to have a wider range of possibilities on the job market. If not, they try to develop new skills and gain knowledge on paid courses after finishing their studies and finding a job because the course they graduated from is not for them. This is the purpose of many changes, huge rotation on job market and thousands of CVs (Curriculum vitae) and motivational letters that human resources management has to deal with and due to such actions people have to wait weeks or sometimes months until they receive answer telling that they are suitable people for that place. This is the cause created by the time needed to check if the person is suitable for the place and fulfills all the requirements. It is nearly impossible to remember all the candidates so statistics have to be done and among those people several are chosen, calls are made and then we can really start the recruitment process [21, 22]. This could be fastened due to implementation of new technologies, that would be helping people from HR (Human resources) department confirm their duties faster and allow them to take care of other exercises waiting for them.

Thanks to the development of information technology, artificial intelligence and robotic process automation, recruiters could be relieved from some of their duties. New technologies, programmes or even machines may be implemented and introduced to the daily life of those employees.

At the beginning, the system would be taking care of preliminary phase of recruitment which would be the candidates selection by information given in their papers. This could shorten the waiting time for about a half and allow recruiters to just check if the correct CVs have been taken and not spend our in front of the wrongly made ones. In the presented system all of the requirements must be implemented, all the content to which HR management people pay attention will be included in order to check if the programme has been correctly made. At first the system will be in testing phase so all the CVs would be checked by the computer along with the recruitment service [23] which will consume same amount of time but after implementing all of the solutions, correcting mistakes and getting on the right track this process would make a significant difference for the companies. When this phase will be made, the presented system should independently accomplish all the operations and give the manager a list of all people suitable for the position. In the next phase the system may be developed in such a way that an email would be send automatically to the candidates who have successfully gone through the qualification process to let them know that they are taken into consideration in the next phase and should wait for a contact from a consultant or they will receive a mail with ready date and time of the meeting they should go to if they want to get that job. What is obvious, if a person does not qualify for the place, an email with such information will be also send back.

Aforementioned features are not the only ones that may be implemented for the programme. The presented ones are just the beginning and they will be created with the prototype. If the prototype will succeed, then further features may be added to

increase programme efficiency, lower the costs of having employees and allow HR department to take care of other tasks not considering looking through CVs anymore. The exemplary features will be monitoring the employees, their work and awarding them with benefits if they do everything according to the plan or warning them if their job is all the time missing something but those features will be described lated when we will speak about further development of our system.

That innovation could lead people working human resources department to many simplification and save of time so they can take care of other activities instead of wasting time on looking through the CV in order to separate and select the proper candidates.

4 General Description of Solution

Our solution is going to provide the company with an efficient automatic filtration of CVs which will be an irreplaceable tool helping during recruitment process [24, 25]. Our project will be replacing people at their places and raise the efficiency of the company. The number of duties of one system could be easily separated between several employees but considering the fact that AI robots will appear in our company this process would be omitted and several employees could be fired and lose their workplaces. Main advantage would be that CVs will be separated to the groups of CVs of people who qualified for the job and the refused ones but in the future the lists may be developed in such a way that instead of dividing CVs on the useful and useless ones there will be an option of sorting CVs to several different profession at the same point and make the employees save more time then it was predicted at the very beginning. The selection of the CVs will be very precise to give the HR specialists clear lists of candidates fulfilling all the requirements. The system must be properly implemented to not give any false information and prepare reports after scanning all the data. The prepared reports will consider data about the employees who could be possibly hired for the place and with whom the company should contact in order to check the skills of future employee and hire a proper person. Apart from the names and skills required for the position, from the report employees will be able to take information about the forms of contacting the candidate, his availabilities, working expectations and information whether an email considering information about recruitment meeting has been sent or delivered or not. This means that the reports will consider also the preliminary information about the time and date where the recruitment speech will take place. The whole recruitment process can be seen in Figs. 3 and 4. In the next chapters it will be described in details.

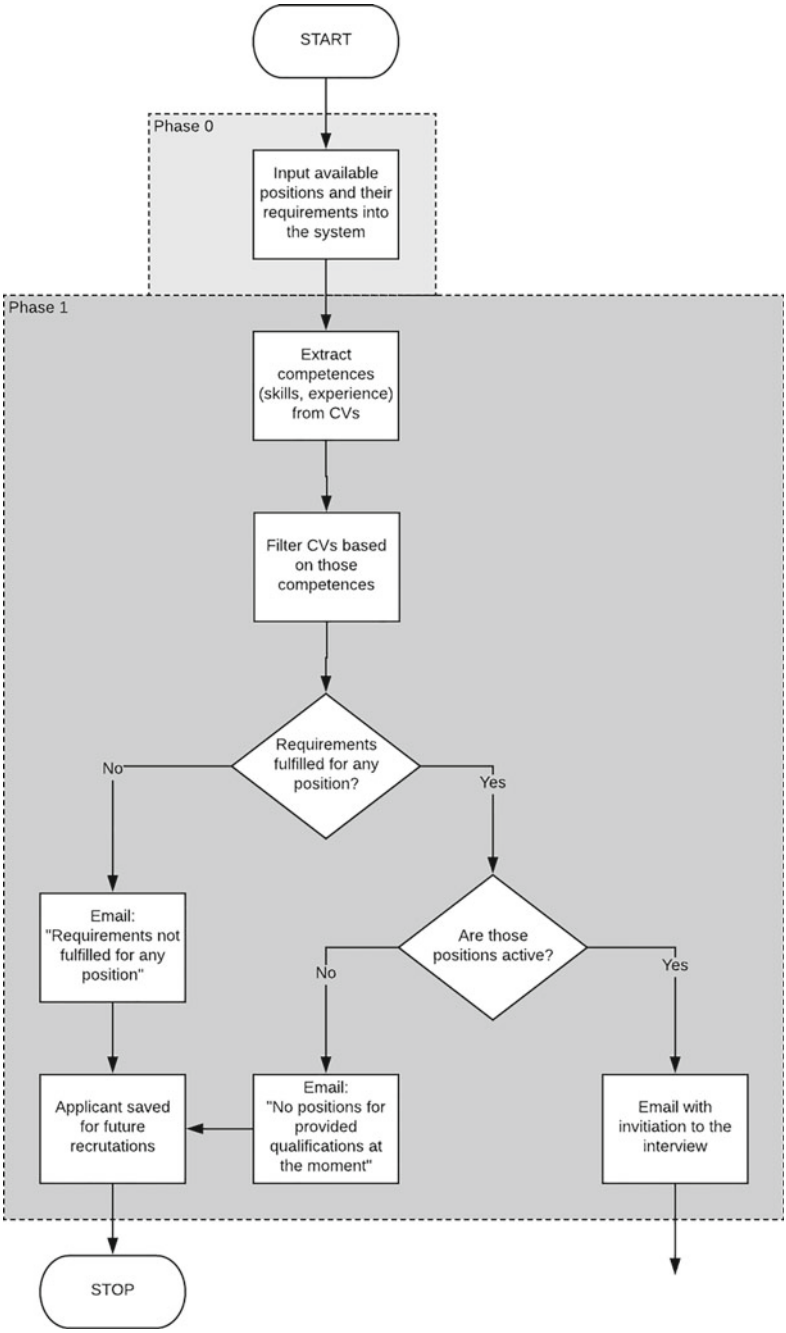


Fig. 3 Flowchart of recruitment process—part I

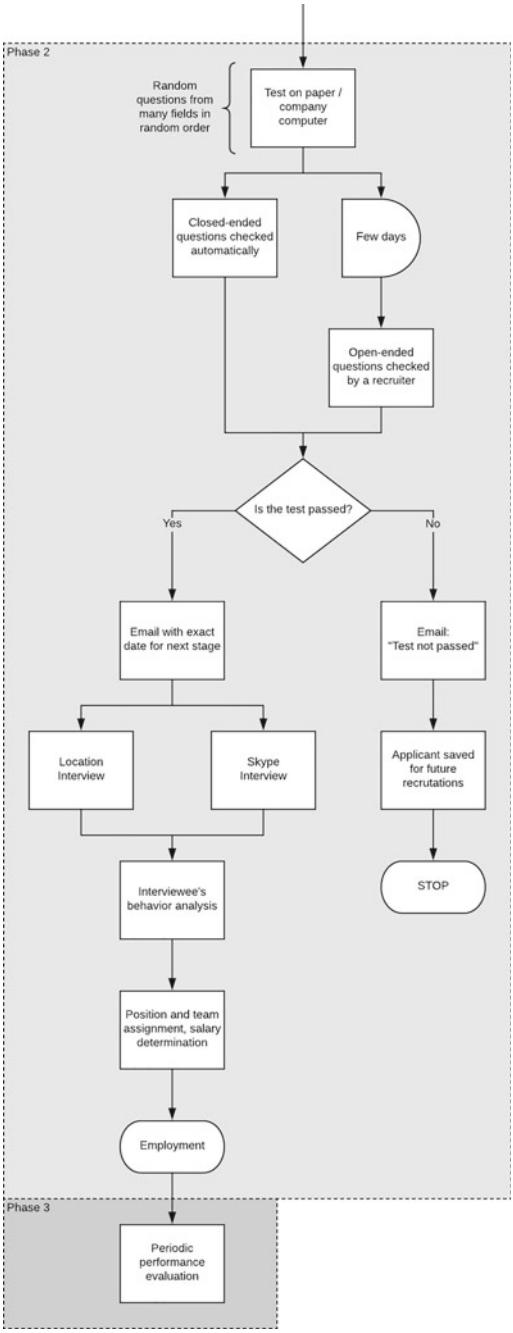


Fig. 4 Flowchart of recruitment process—part II

5 Phases of Recruitment Process

5.1 Phase 0—Setting up Offers for Job Positions

First of all, before setting up the application, people from HR group has to analyse, which types of jobs are needed at the given company. Depending on the field of company's operation one can create job positions that can should be available for recruitment process (see Fig. 5).

While having the needed jobs positions one should determine the required skills for each of them and start writing the description of the position which will be placed in the future job offer. The next step is to point out clearly defined skills required from the candidate. Our application will automatically analyse the description of the position and will make a list, in which there will be skills such English, Java, SQL and being opened for challenges. An employee from the HR group can modify these lists by adding or removing new skills. Please note that the entire list will be used by our application in the future to verify the employee. The technical skills will be checked during tests in the third phase, while the soft skills will be checked in the following one, therefore the list of requirements should be succinct and not too vast. It is also preferred to provide the expected level of proficiency in knowledge of listed languages and technologies on a scale of **1–5 stars**, where 1 means basic knowledge,

Fig. 5 Diagram of Phase 0

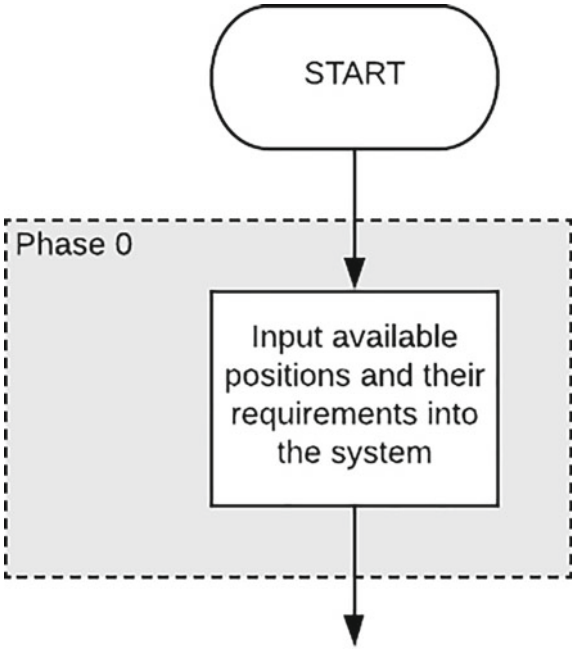


Fig. 6 Choice and ratings of required skills for job position

and 5 a full understanding of the subject. Example can be seen in Fig. 6. On the next page.

Moreover, sometimes in companies there is for instance demand for a given position, and then after a right person is found is becomes obsolete. However, after few months it is common that the position is needed again, since in big companies there is high turnover rate. In order to simplify this our application will offer option to set the current job offer to "**inactive**", so it will disappear from the website until it is activated again.

In the future one can also think about automatic propagation of the job offers to locally popular web services for job searching such as LinkedIn, however one has to remember that if the offer in on foreign service it is still required for an future employee to send their CV, since it will be automatically analysed by the application, what is further described in the next phase.

5.2 Phase 1—Filtration of CVs

After the deployment of jobs offers on the company's website, one can expect many cover letters and CV to be sent.

Even today, many companies already have an automatic CV scanning procedure, which search the key information and skills required for the given position. Our application will also use such a function.

A virtual account associated with the applicant will be created and filled in with data from CV such as address, name, surname and acquired technical skills. The computer will then decide whether the applicant is suitable for the applied position or related position. One has to remember that in large companies there are often many similar positions, so the system should provide information to employee from

HR which jobs positions are appropriate in the given case. The acquired skills and features will be then used in the next phase of recruitment in order to prepare a skill test before the interview (see Fig. 7).

If the system decides that the applicant does not have the required skills for any company, then an automatic message will be sent back to the email address that will look like in Fig. 8.

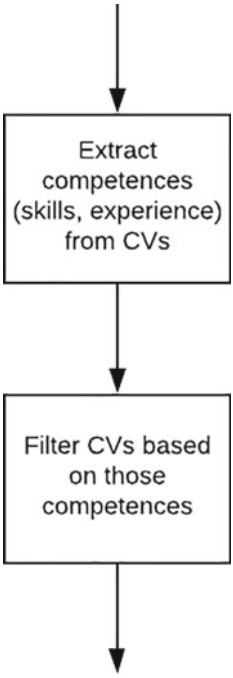


Fig. 7 Diagram of Phase 1—part I

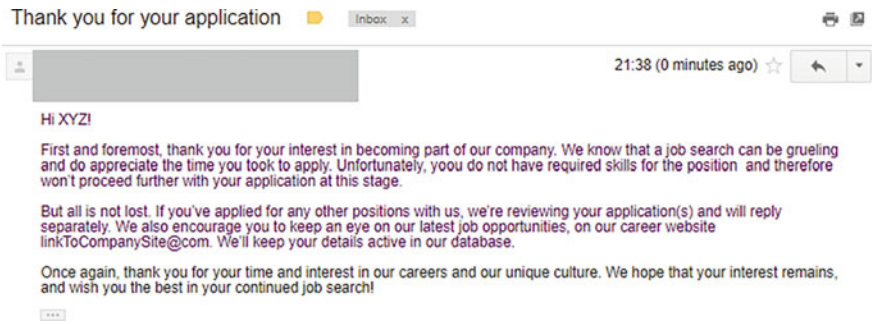


Fig. 8 Exemplary email for applicant without necessary skills

In the case when it turns out that the future employee has the appropriate features for other job, which he did not applied at first, he will be also informed about that to encourage him/her (see Fig. 9).

There is also a possibility for the situation in which the person submitted the application, but during its processing or even before sending the CV, the position has become inactive or one has took a stand of it. In this case, an appropriate email will be sent which will tell that the applicant has indeed the required skills (or not), but the position is currently unavailable and that the company will automatically sent in the future e-mail when it will be interested in employing him/her, which can be read in the Fig. 10.

If the application will decide that the applicant has required skill and the job position is still opened it will try to arrange a meeting for the test. At this point there are two possible scenarios.

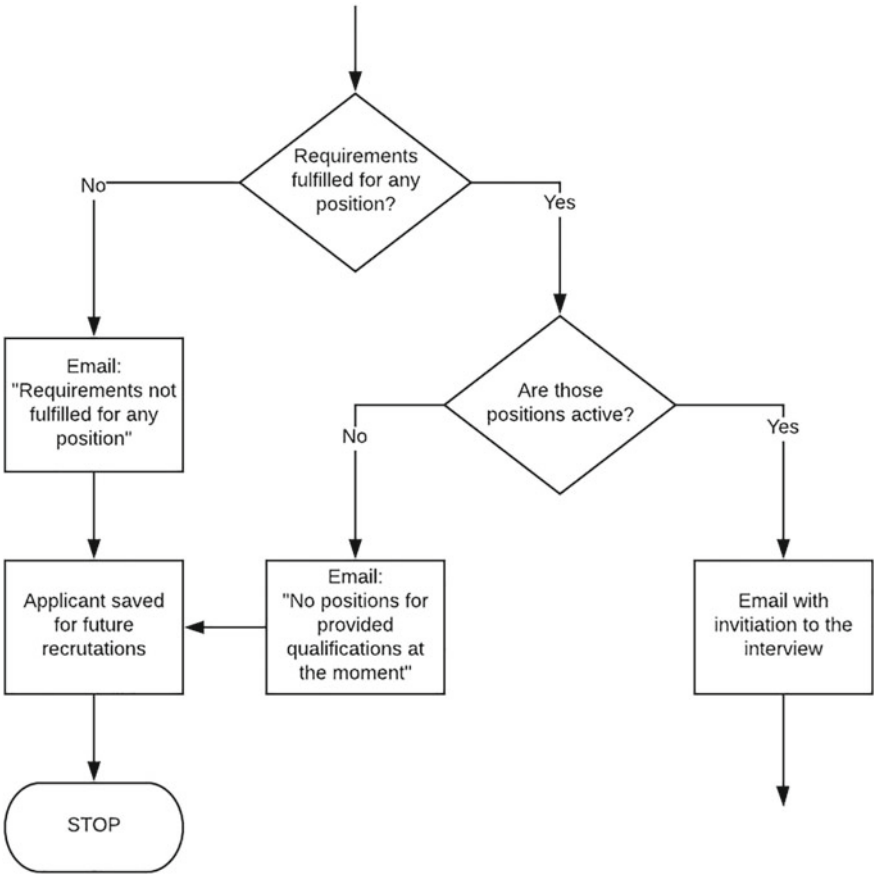
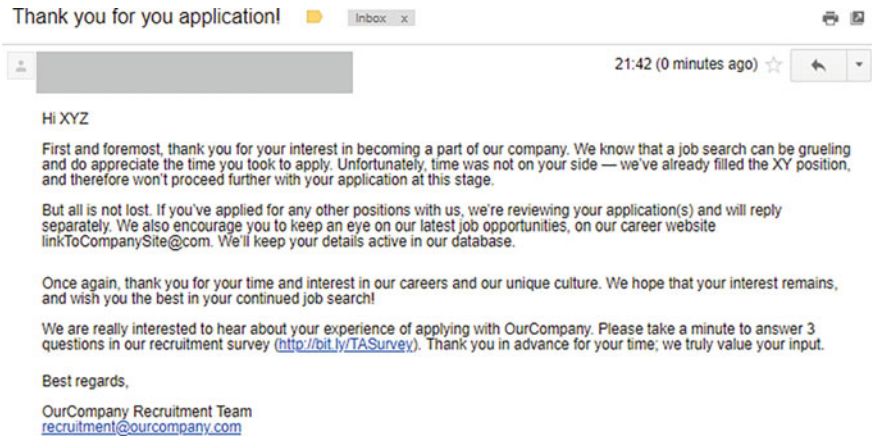


Fig. 9 Diagram of Phase 1—part II


Thank you for you application! Inbox x

21:42 (0 minutes ago)

Hi XYZ

First and foremost, thank you for your interest in becoming a part of our company. We know that a job search can be grueling and do appreciate the time you took to apply. Unfortunately, time was not on your side — we've already filled the XY position, and therefore won't proceed further with your application at this stage.

But all is not lost. If you've applied for any other positions with us, we're reviewing your application(s) and will reply separately. We also encourage you to keep an eye on our latest job opportunities, on our career website linkToCompanySite@com. We'll keep your details active in our database.

Once again, thank you for your time and interest in our careers and our unique culture. We hope that your interest remains, and wish you the best in your continued job search!

We are really interested to hear about your experience of applying with OurCompany. Please take a minute to answer 3 questions in our recruitment survey (http://bit.ly/TASurvey). Thank you in advance for your time; we truly value your input.

Best regards,

OurCompany Recruitment Team
recruitment@ourcompany.com

Fig. 10 Exemplary email in case of free job positions

(1) Person from HR group will formerly define in which hours he/she will have free time at work and the system will automatically assign the time in this interval. For instance: A given employee has free time on Wednesday from 10:00 to 14:00, consequently the system will automatically sent the email with invitation for the test that will be held from 10:00 to 11:00.
(2) A special notification will pop up at the computer of HR group with the request to choose meeting time manually.

Such a prepared e-mail will contain all needed information such as time, data and place for meeting. It will also ask if the applicant is available at that time and offer him a possibility to change the date. One can also call the company if they want to arrange the meeting personally.

5.3 Phase 2a—Recruitment Tests

The next phase of the recruitment process is dedicated to checking the real skills of the candidate. After CV is checked and the data included in it, shows that the applicant is meeting the requirements for the position, that is currently open, system sends him the invitation on the interview. In fact the actual interview is only the part of the process of determining if the person can take the position. The procedure begins with the test.

This test is from the fields important for the given job, for example if it is connected to programming, questions would be about appropriate technologies or languages. In order to make this process automatic, required is the database of questions and tasks categorized and marked in the difficulty level. Everything will start from determining, what fields of knowledge are required to be checked. This will be assigned of what are

the requirement for the positions fitted for investigated person's CV and the guidelines for opened jobs. With this information random questions from appropriate categories are pulled from the database and the test is prepared by the program (see Fig. 11).

This test may be taken in the paper version or the digital one solved on the computer in the company. Today many test for the companies are solved online. It is very convenient for the applicant, however it also causes, that exam questions can easily be copied and spread in the internet and other sources. In such situation, no matter how big is the question pull, the new applicants may have contact with them already, what makes the test result to be unreliable. The other aspect, that helps in preventing the escalation of test outside the company, is the fact, that the questions on the tests are not in order of the categories, they are in random order, what makes it more difficult to remember after the test.

The test consist of certain amount of tasks, from different fields and of different types. There are closed question with given four possible answers and goal of choosing the correct one and open questions in which the applicant will have to

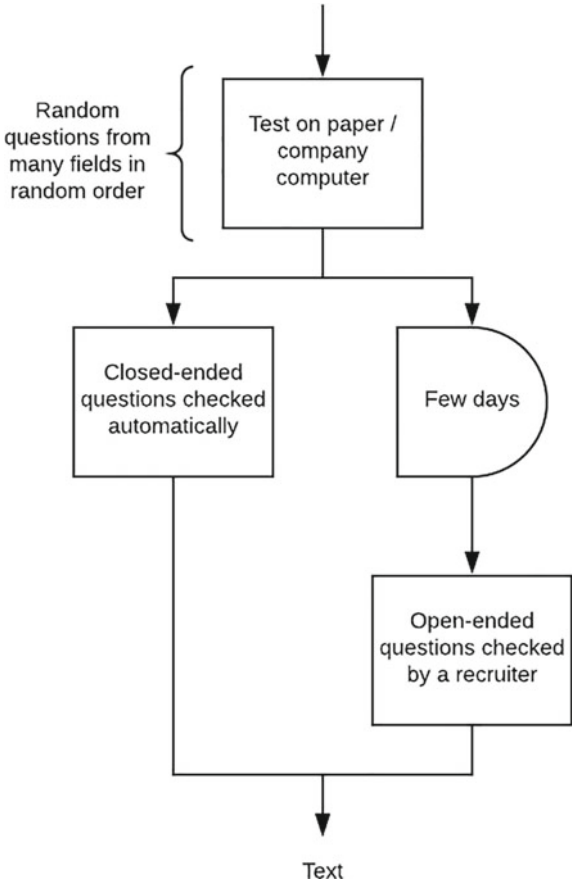


Fig. 11 Diagram of Phase 2a

write his own answer. In terms of grading those questions the checking of the closed tasks can be automated if the test is performed on computer, simply by the program, by just finding which answer was marked and if the test was performed on paper, by scanning it and later performing similar action. The open question unfortunately cannot be automated, at least for now. Because of that there is the need for the person which will be evaluation open task and grading it with previously established scale and later introducing it to the system.

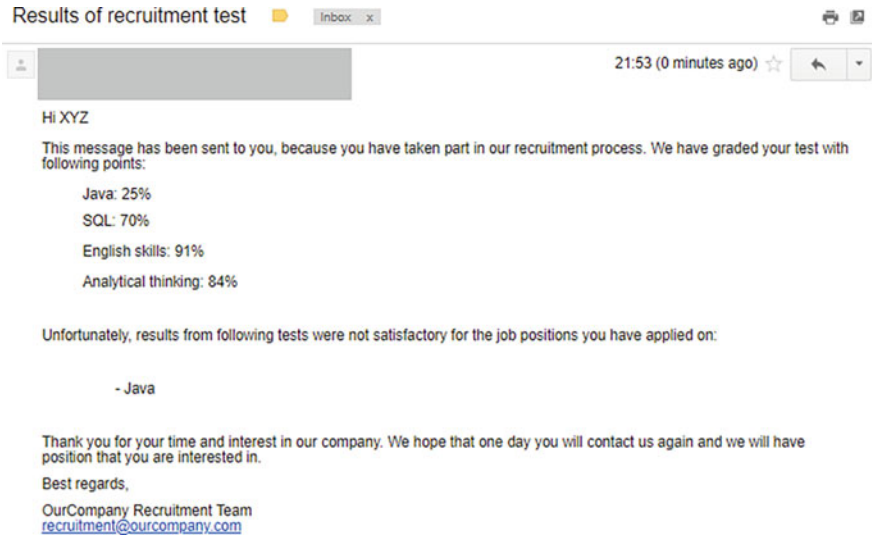
As previously mentioned the topic of the tasks is strictly connected to the character of the open positions. For that the questions from those fields are taken from the database and put in random order. The other element of the test are the questions for soft skills. Those types of questions have a purpose to test the analytical thinking of the candidate, for example, sorting algorithms or general knowledge from Information Technology. Also they can take a role similar as in the interview to collect more knowledge about the candidate from himself as "Have you ever experienced hard situation in your life and how did you deal with it?". In this way it is possible to get more initial impressions about the applicant and decide it is worth to invite him to the next phase. Also the good aspect of those questions typically reserved for the interview is the fact, that some people find it easier when they have some time and write the answer, instead of for the answers in quick moment.

After candidates come to the company's headquarters to write the test, it needs to be evaluated. Closed questions are checked by the application, open questions are checked by the recruiter, and the score is put in the system. This process should not take more than a few days, and after it's finished, the mail is sent to each with information on whether they passed the test. if they did, the date and time of the interview will also be given in Fig. 12.

5.4 Phase 2b—Job Interview

After successful part of sorting CV and being chosen, the process of recruitment will begin. Candidates will be firstly asked to take part in an interview. Here they will have ability to make a choice which would be more convenient for them. Such options will be skype conversation or physical appearance in the company and holding the speech there. Both cases will be equally suitable for the company because the candidates will be observed by a camera analysing the behaviour of the candidate so in each case the conversation will be almost the same. The algorithm implemented will check the look of the face of the candidate and gestures to give output if the candidate is lying, cheating or doing other unpleasant things (see Fig. 13).

Skype interview will be one of the possibilities to choose for a recruitment speech. This would be an innovation for a recruitment speech allowing many people to fit of better to their daily schedule. During a speech, a camera will be precisely observing the candidate in order to read his face. His feelings will be read from the mimicry, and all the confusion, lies, and others will be discovered immediately. The system will also focus on the eyes of the speaker. During Skype speech, the candidates may



Results of recruitment test Inbox x

21:53 (0 minutes ago)

Hi XYZ

This message has been sent to you, because you have taken part in our recruitment process. We have graded your test with following points:

Java: 25%

SQL: 70%

English skills: 91%

Analytical thinking: 84%

Unfortunately, results from following tests were not satisfactory for the job positions you have applied on:

- Java

Thank you for your time and interest in our company. We hope that one day you will contact us again and we will have position that you are interested in.

Best regards,

OurCompany Recruitment Team
recruitment@ourcompany.com

Fig. 12 Exemplary email with test's results

be trying to cheat and put some papers invisibly around the computer, but if their eyes are moving, looking for the answer, the system will inform us about it. To prevent candidates from using the Internet, they will be asked to share the screen while the speech is held.

To record facial expressions, and emotions and monitor the general behavior of a potential worker, Affectiva software [26] can be used, which provides high-level solutions and ready-to-use tools. This platform has a built-in module which allows connecting with machine learning programs [27–29]. Due to this solution, after several recruitment processes, our platform will provide better results in finding skilled workers and managing teams.

Local interviews are preferred by the companies. It gives HR people more possibilities to check candidates, take control of them, and monitor their behavior. The candidates will be observed constantly, their gestures, face mimicry or eyesight will be under constant monitoring of a recruiter. Of course, the cameras with our implemented programs will also be used to compare the results from the program with those from a recruiter. After such analysis of results, the right decision may be made considering the candidate and his competencies considering the place he is applying for. It will also be easier to give candidates some tests to solve and then quickly mark them in order to grade the level of references.

During the recruitment phase the candidate will have firstly technical and language knowledge checked. Those two factors have the biggest impact on the final result and of recruitation because of those factors are not fulfilled then the candidate has no chance to get place in our company. Those skills will be checked during the speech by tests and talk on the date estimated by HR specialists and candidates. Character is another worth mentioning point according to which the expectations, position and

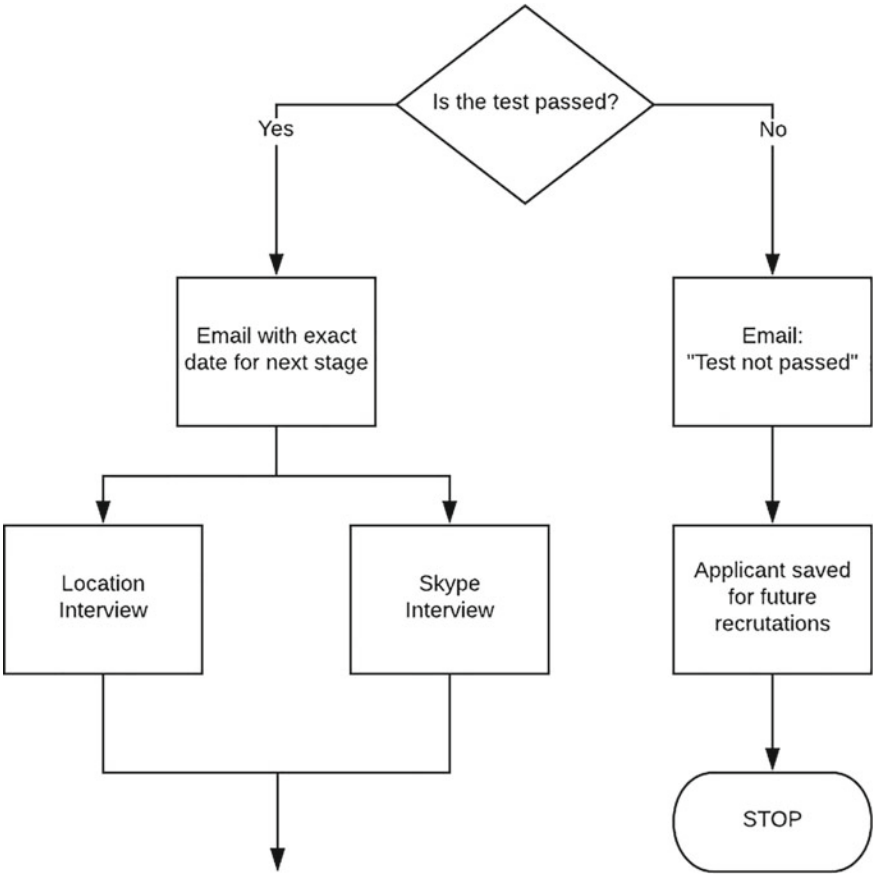


Fig. 13 Diagram of Phase 2b

clients will be assigned. Social networks will be manually checked by recruiters in order to check photos, posts and groups people are assigned to in order to hire suitable new employees whose will be suitable for the politics of our company.

Candidates by the end of recruitment will be asked to tell their expectations considering job. Their expectations may consider health care, free days, benefit cards, money earned, bonuses, and the possibility of getting a better position in the company. All of those aforementioned will also be taken into consideration during the speech; the machine will also make some recognition on the market to see if the expectations are not too high and suitable for the applied position (see Fig. 14).

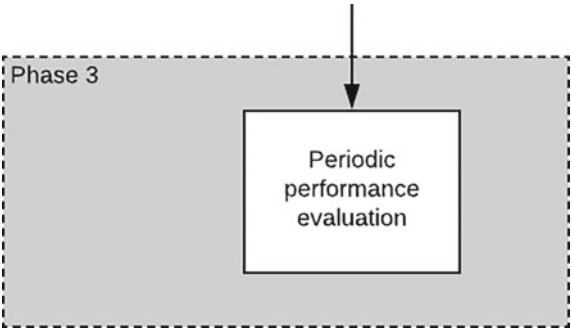
After finishing the recruitation, results will be saved in the database of the company. Candidates whose skill were not enough or there were some doubts concerning them, will have special adaptation next to their profile so in some case like one of the accepted candidates refuses to take our offer or after selecting the candidates there will be still free spaces so we could faster get to people who could

Fig. 14 Diagram of Phase 2b—final step

be taken one more time for testing and then may be taken as an employee to our company.

The reports from the camera will be also added to candidates profiles in order to be familiar with their behaviour. This will definitely help with dividing tasks between employees. If the employee gets easily confused, stressed or is disorganised then such a person will be assigned to office work and not have any contact with clients in order not to scary the client and lose the potential source of money and tasks. Opposite to workers who have significant contact with customers, know what they want, and can convince clients to invest more, widen the project in order to gain more benefits and money at all.

Fig. 15 Diagram of Phase 3



5.5 Phase 3—Future Development

The future of the system may be crucial for the development of the company and its employees. The way in which it will all go will also have great impact on the future of the companies and HR departments. Instead of only selecting the proper candidates for employees and sending them information about the recruitation and checking candidates skills the programme may have additional features added.

The first change would be monitoring employees work, their results and deciding whether they should be awarded a pay rise or warning. The system will be connected with employees accounts, then monitoring their working time will be possible. The data, progress and project created will be visible for our robot as well as the schedule of the employee. If all the tasks have been done according to the plan, the results are satisfactory and there are no delay, the system will send an information to the HR department about suggesting the pay rise to the employee to reward his skills, dedication and motivate for further development. What is more if the employee will not be sticking to the projects, do prohibited things with their computers at work or miss all the deadlines the system may suggest to fire that employee and look for someone else for his place (see Fig. 15).

The next change will be monitoring the work of the groups of employees. Every team would have a project to complete which must be divided fairly between all of the group members. Unfortunately not all of the members may feel good in the tasks assigned to them, so the system will be used to analyse the progress of the groups and targets and goal and try to define whether a change in that team is necessary or not. The change may consider, team leader change, project change or just change of one or two employees in order to raise efficiency and fasten the processes in the company. In special cases there will be a possibility the assign already started projects to other groups but only in case that the group will totally not be able to do anything with it.

6 Advantages of RPA and AI in HR

The newly developed systems which consist of artificial intelligence and robotic process automation are the future of companies, machines and processes in HR. This may simplify life of people working in that department, shorten waiting time of candidates and allow the company to move to another level of services but this are not the only advantages. The rest of them will be mentioned in following points.

1. The introduction of RPA and AI in HR will definitely cut the costs and allow companies to save money. First of all, list of employees will be definitely shortened. This will be the main occurring change causing the whole chain of changes to appear. Created system will replace people in some tasks which means that some of the employees will not have anything to do at the place and some of the duties of the other employees will also disappear. Employees will be slowly fired because computers will replace them and employee who does not have any activities is useless because nobody will be paid for doing nothing but this will bring lost of financial benefits to the company which is one of the main reasons of opening a business. In that case that process will look in such way that system will replace people, less people will mean less workplaces and less computers, just several people will be needed to analyse reports generated by the robot.
2. The other benefit for company owners will be the reduction of working time of HR employees. Despite firing lots of people, the ones that will stay may have shortened working hours or change their agreement from full-time to part time job because of lacking duties.
3. The next worth mentioning point is higher efficiency provided by the machines. Many responsibilities will be taken from employees and given to the robots so employees could take care of other activities while robots will be making their previous time-consuming job. Employees instead of spending many hours, reading the CVs, selecting the proper ones and analysing all the data will be able to do other tasks while those will be made by robots. This will help the companies to have everything finished on time and do not wait for some results longer than expected. Worth mentioning point is also giving HR managers new tasks to fulfill all their working time if they will stay with full-time job to increase efficiency and pay them money for the job, not for doing nothing.
4. Moving on to the robots and system, we should remember about the better choice of employees for the place. Robots will stick strictly to the requirements given and implemented functions. Their selection will be more accurate because they will look only for the clearly given points, without looking at others or trying to cover some points with other which may not be directly connected. That point gives our machine a great advantage over traditional candidates selected by the HR department.
5. During the recreation process, some well-skilled candidates who were perfect for someplace faced a problem that could not be overcome easily, and it was being a friend or family of a recruiter. The truth is that many well-skilled employees cannot find a job despite great qualifications, technical background,

and knowledge possessed just because one of the candidates has great contact with a recruiter, and that is the only reason for hiring unskilled employees. Our product will prevent the formation of such a situation. Only professional skills and working experience will be taken into consideration in order to hire the best possible employee for the development of a company.

6. In the next phases of recrutation our robot will have one of the hardest tasks to do which will be the controlling the interviewed person. All of the recruitment speeches can be hold by Internet via Skype or other free to use programme in order to ensure everyone with some comfort. All of those conversations will be recorded and checked by our product in order to know where was the client looking if it was direct to the camera of was the sight going somewhere else in order to look for some information or read some hints to make good impression on the interviewer. Some face or feelings recognition could be also included in the project, that would tell us if the candidate lies or tells the truth. That could show the lack of confidence or some sort of knowledge of the interviewed person in order to know some character features and check how this person reacts for such situation.
7. The last but not least point is making an advertisement for our company using the AI. That is the newly created system not widely spread, not known for many people so using such a system for the purpose of advertisement would guarantee an immediate success and show the development and advanced technologies used in the company which will be attracting new candidates to come to our company and work in such developed environment. This will be one of the keys to success.

All of the mentioned points are the main advantages of RPA and AI usage in the company but it is just a beginning. More solutions will be implemented later after the first point which is AI in HR brings benefits and people will convince themselves to it.

Below one can see a brief summary of the advantages given by usage of RPA&AI in form of Table 1.

Table 1 Summary of the advantages of using RPA&AI

Main advantages	With RPA&AI	Without RPA&AI
Cutting costs on employees	+	–
Shorter working time	+	–
Higher efficiency provided by machines	+	–
Focusing on particular skills	+	+
No hiring unskilled people who are friends of recruiters	+	–
High level of observation of candidates	+	+
Good advertisement to showing progress of the company	+	–

7 Legal Aspects

While considering each of the steps included in the recruitment process [30] it is essential to take into consideration their ethical and legal repercussions. While the former aspect could be debated over and its abidance is not always necessary and frequently depends on subjective and specific decision of a committee, the latter one is strictly regulated in numerous legislations and has to be followed regardless of the situation.

One of the most notable laws is called General Data Protection Regulation (GDPR). It was created on 14 April 2016 and comes into effect on 25 May 2018. Since this date, every organization which collects and processes data of citizens in European Union countries will have to comply with the rules prescribed in the Regulation. Any infringement of them may result in severe administrative fines either to the company or the natural person committing the offence. However, the main idea of the Regulation is the unification and simplification of laws of all European countries concerning the privacy of their citizens. This has been done by inclusion of number of articles regarding the subjects such as data pseudonymisation, designing the information systems with privacy in mind and enabled by default, easier access to the data being processed or the usage of plain language understandable for everyone in the policies of the companies [31].

The article, which is most relevant to the previously described algorithm of recruitment process, talks about profiling and in particular the techniques allowed for its execution. According to the given definition, profiling includes any means of utilizing personal data to perform automatic evaluation of natural person's status, such as their performance at work, economic situation, health, personal preferences or interests which produces legal or similarly significant effects concerning him or her. These groups also include recruiting practices without any human intervention. In this article it is stated that any person has the right not to be subject to such an automated system, unless it is used under the pre-specified conditions. One of these exceptions is its utilization to attest the correctness and efficiency of execution of a contract between the employee and the employer.

It is also worth mentioning that for attaining and maintaining the fairest and most transparent rules during the automated evaluation appropriate mathematical or statistical procedures [32] should be adopted and any inaccuracies or errors resulting from these operations should be minimised.

The other category of personal data, which has to be mentioned when dealing with decision making about the person's future are the sensitive data, such as their racial or ethnic origin, political opinion, religion or beliefs, genetic or health status or sexual orientation. It is forbidden for the company and especially their automated systems to classify or discriminate against a person because of it and as a result put them in a disadvantageous position in comparison with the other candidates during the recruitment process. The same category also includes.

Finally, each of the stages of recruitment, which deals with personal data of the candidate has to be accompanied by a separate, freely given and specific consent in

a clear form, preferable written. For each of them, the purpose of data processing, and in particular profiling, its methods and consequences have to be openly stated to the applicant and must be accepted with their affirmative action. The lack of such activity is equivalent with their disagreement. Additionally, every person has the right to audit the personal data which have been collected about them without obstacles or additional fees from the employee.

8 Time Savings and Optimization Assessment

In order to evaluate optimization that comes with deploying our application, one need to analyze time spent on each individual task. There are 5 steps that can be separated.

1. Firstly, one can assume that in an enormous company there are about 30 CV sent weekly and average employee from HR group has to spend about **5 min** to read each one.
2. Secondly, one can assume that about 25 CVs will pass the first step, so that the employee has to create a account in database with all necessary information about each person what can take around **30 min**.
3. Such a HR employee has also write an email in which he will invite an applicant for a test or say the position is currently filled in or person lacks some of the skills required for the position. Such a task can be estimated for no more than **10 min**.
4. After the tests, one has to firstly grade the answers (what can be also optimized by the machine), write them into database and generate a report. In case of usage of our application one will save here around **15 min** for each person.
5. Lastly, one has to send an email with results and information about further recruitment process what will also take around **10 min**.

All the time optimization can be seen in Table 2. It shows time spend for each task, per person, weekly and monthly.

As one can see, with the use of our application a company can save up to 6300 min per month, what is also equal to 105 h. Therefore it can be said that the application saves around **0.66** of **Full Time Worker (FTW),** assuming that a typical employee works **160 h** in a month. (Also called **FTE—Full Time equivalent**).

One can also analyse the percentage share of each task in Fig. 16. Mostly the time is saved during the writing the data into database and checking if applicant is suitable for various positions.

Table 2 Evaluation of resources required to spend in the recruitment process

Task to be done	Number of people/ repetitions of the task weekly	Time spent per repetition [min]	Time spent weekly [min]	Time spent monthly [min]
Read CV and evaluate	30	5	150	600
Write info into DB and check other positions	25	30	750	3000
Write email response [invitation or turndown]	25	10	250	1000
Generate report of test's results	25	15	375	1500
Send 2nd email	5	10	50	200
			SUM:	**6300**

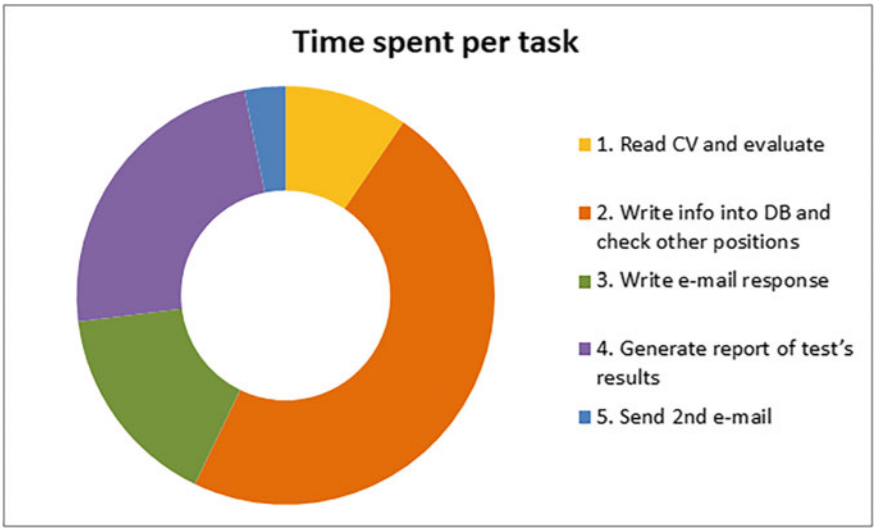


Fig. 16 Percentage share of each task

9 Future Development of Our Project

The first possibility is the usage of Ansible. It is an automation tool used particularly in IT that automates cloud processing, configuration management, and application installation. It is lightweight software that does not need any additional configuration or programs. It uses a very simple language (YAML) that allows to automate many

different tasks. Our platform could be installed on many computers and servers with just one program. There is no need to install software physically on every machine.

Our project focuses on recruiting people, generating tests, controlling the cooperation of hired teams, and managing payroll and benefits. However, there could be expanded functionalities such as intelligent and automatic chatbots. Their purpose could be supportive for employees as well as people who would like to get know some information about the company or have questions about a job they apply for.

10 Conclusions

In the modern world global development allowed society to become much more mobile and change their lives much more often. People move from place to place because of education, work, or just personal preferences. That situation created the biggest rotation in the job market in history. This also puts pressure on the Human Resources systems of all the companies since they receive more applications than ever before and need to go through them in a reasonable time and choose the most suitable candidates for open positions. This sort of task today is still mostly performed by humans, who have limited capabilities in this sort of task. The recruiter needs to read all the applications, make statistics out of them, and decide which ones should be considered. This process takes a lot of time, from the moment of receiving the CV to the call inviting the interview and, finally, after that, the information if the company is interested in hiring the person. This is all caused by the inability to process such a large amount of information with standard methods.

The use of modern information technology, robotic process automation [33] and artificial intelligence [34–36] can improve this process. The new technologies can make it faster and more accurate allowing to free the time of recruiters and allowing them to focus on other important tasks. The goal of this project was to create a system that would allow us to do that. Such a solution, at the beginning, should collect the CVs sent with the applications to the company and analyze them with the use of keywords, determining what skills are included in the document. Later, this information is saved in the database. The system holds the list of actual open positions in the company with requirements for them and compares if any candidate could be suitable for it. If such a case arises, automatic mail is sent inviting the test to the company's headquarters. The test cannot be performed remotely, because of security reasons and to prevent the spreading of tasks outside of the company. The purpose of this test is to check the real skills of the candidate required for suitable solutions. After the test is written, it is graded by the system and recruiters. If the result comes out positive, another mail is sent inviting on the interview, which can be performed in the headquarters or remotely. The system also has the function used for this, where it evaluates the behavior of the candidate during the conversation. If the candidate, after all the stages, seems to be suitable for any open position, system informs the Human Resources about that and recommends the candidate.

The described system uses Robotic Process Automation and Artificial Intelligence, which, in consequence, creates a lot of advantages for HR. After the initial investment, the costs decrease by decreasing the required amount of employees in the department since less amount of recruiters are required to analyze the system outcomes with proposed workers, and their time is better spent not wasting on unnecessary tasks. The system also, with time, will improve its performance, making better recommendations for candidates due to its AI element, which is constantly learning. The whole outcome of the project shows that the new technologies implemented in the Human Resources department can significantly improve the functioning of the company.

References

1. Hofmann, P., Samp, C., Urbach, N.: Robotic process automation. Electron. Mark. **30**(1), 99–106 (2020)
2. Van der Aalst, W.M., Bichler, M., Heinzl, A.: Robotic process automation. Bus. Inf. Syst. Eng. **60**, 269–272 (2018)
3. Ivančić, L., Suša Vugec, D., Bosilj Vukšić, V.: Robotic process automation: systematic literature review. In: Business Process Management: Blockchain and Central and Eastern Europe Forum: BPM 2019 Blockchain and CEE Forum, Vienna, Austria, September 1–6, 2019, Proceedings 17, pp. 280–295. Springer International Publishing (2019)
4. Artificial intelligence and robotics: Separating reality from the hype—Opinion—outsourcing—sourcingfocus.com [WWW Document] (n.d.). http://www.sourcingfocus.com/site/opinionscomments/artificial_intelligence_and_robotics_separating_reality_from_the_hype/. Accessed 8 Apr 18
5. Ariely, D.: Predictably Irrational: The Hidden Forces That Shape Our Decisions. Revised and Expanded edition. Harper Perennial, New York, NY (2010)
6. Artificial intelligence | Definition, Examples, and Applications [WWW Document]. Encyclopedia Britannica. https://www.britannica.com/technology/artificial-intelligence. Accessed 21 May 18
7. Benefits & Risks of Artificial Intelligence [WWW Document] (n.d.). Future of Life Institute. https://futureoflife.org/background/benefits-risks-of-artificial-intelligence/. Accessed 9 Apr 18
8. Syed, R., Suriadi, S., Adams, M., Bandara, W., Leemans, S.J., Ouyang, C., Reijers, H.A., et al.: Robotic process automation: contemporary themes and challenges. Comput. Ind. **115**, 103162 (2020)
9. Aguirre, S., Rodriguez, A.: Automation of a business process using robotic process automation (RPA): a case study. In: Applied Computer Sciences in Engineering: 4th Workshop on Engineering Applications, WEA 2017, Cartagena, Colombia, September 27–29, 2017, Proceedings 4, pp. 65–71. Springer International Publishing (2017)
10. Cooper, L.A., Holderness, D.K., Jr., Sorensen, T.L., Wood, D.A.: Robotic process automation in public accounting. Account. Horiz. **33**(4), 15–35 (2019)
11. Boulton, C.: What is RPA? A revolution in business process automation [WWW Document]. CIO (2017). https://www.cio.com/article/3236451/business-process-management/what-is-rpa-robotic-process-automation-explained.html. Accessed 10 Apr 18
12. Capgemini Consulting: Robotic process automation (RPA) The next revolution of Corporate Functions [WWW Document] (2016). https://www.capgemini.com/consulting-fr/wp-content/uploads/sites/31/2017/08/robotic_process_automation_the_next_revolution_of_corporate_functions_0.pdf. Accessed 9 Apr 18

13. Ostdick, N.: The Value of RPA in the Telecom Industry [WWW Document] (n.d.). https://www.uipath.com/blog/rpa-and-telecommunications. Accessed 9 Apr 18
14. Benko, A., Lányi, C.S.: History of Artificial Intelligence. Encyclopedia of Information Science and Technology, 2nd ed., pp. 1759–1762 (2009). https://doi.org/10.4018/978-1-60566-026-4.ch276
15. Tashev, A., Takenova, Z., Arshidinova, M.: Algorithms for solving problems of resources allocation in the management of business processes in educational organizations. Int. J. Mod. Educ. Comput. Sci. (IJMECS) **15**(5), 14–27 (2023). https://doi.org/10.5815/ijmecs.2023.05.02
16. Iskandar, S.E., Fitriani, N.I., Syahruddin, S., Agustina, Y.: Effectiveness of intelligence: intellectual, emotional and spiritual towards employee performance in business organizations. Int. J. Inf. Eng. Electron. Bus. (IJIEEB) **15**(4), 1–12 (2023). https://doi.org/10.5815/ijieeb.2023.04.01
17. PwC: Rethinking Retail: Artificial Intelligence and Robotic Process Automation [WWW Document] (n.d.). https://www.pwc.be/en/documents/20171123-rethinking-retail-artificial-intelligence-and-robotic-process-automation.pdf
18. UiPath: Banking Automation [WWW Document] (n.d.). https://www.uipath.com/rpa-in-banking. Accessed 8 Apr 18
19. Fry, N.: Retailers Should Replicate AT&T's Approach to Robotic Process Automation, and Their Results! Medium (2018)
20. Baroi, I., De, S.: Comparative advancements and challenges of branding strategy in business-to-business scenarios. Int. J. Inf. Eng. Electron. Bus. (IJIEEB) **15**(4), 26–33 (2023). https://doi.org/10.5815/ijieeb.2023.04.03
21. Derach, W., Grabia, S., Grawender, H., Jaworowski, R., Kapituła, M.: Optimisation of Recruitment Process in Global Companies with Usage of RPA&AI. Student Practical Work of Modern IT Methodologies and Services, Poland
22. Sihare, S.R.: Colleges require ICT facilities to enhance educational and employment prospects. Int. J. Mod. Educ. Comput. Sci. (IJMECS) **15**(3), 16–32 (2023). https://doi.org/10.5815/ijmecs.2023.03.02
23. The Wiley Blackwell Handbook of the Psychology of Recruitment, Selection and Employee Retention [WWW Document]. Wiley.com. https://www.wiley.com/en-pl/The+Wiley+Blackwell+Handbook+of+the+Psychology+of+Recruitment%2C+Selection+and+Employee+Retention-p-9781118972694. Accessed 21 May 18
24. Kapse, A.S., Patil, V.S., Patil, N.V.: E-recruitment. Int. J. Eng. Adv. Technol. **1**(4), 82–86 (2012)
25. Doherty, R.: Getting social with recruitment. Strateg. HR Rev. **9**(6), 11–15 (2010)
26. Emotion AI Overview [WWW Document]. Affectiva (2022). https://www.affectiva.com/emotion-ai-overview/. Accessed 21 May 18
27. Staff, I.A. of E., Ao, S.-I., Rieger, B.B., Amouzegar, M.A.: Machine Learning and Systems Engineering. Springer (2010)
28. Omri, M.N., Mribah, W.: Towards an intelligent machine learning-based business approach. Int. J. Intell. Syst. Appl. (IJISA) **14**(1), pp. 1–23 (2022). https://doi.org/10.5815/ijisa.2022.01.01
29. Theodoridis, S.: Machine Learning, NET Developers Series. Academic Press (2015)
30. Headworth, A.: Social Media Recruitment: How to Successfully Integrate Social Media into Recruitment Strategy, 1 ed. ed. Kogan Page, London; Philadelphia (2015)
31. Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation) (Text with EEA relevance). OJ L (2016)
32. Paluszek, M., Thomas, S.: MATLAB Machine Learning. Apress L. P. (2016)
33. Robotic Process Automation: This Is Just the Beginning [WWW Document], n.d. CMSWire.com. https://www.cmswire.com/digital-workplace/robotic-process-automation-this-is-just-the-beginning/. Accessed 10 Apr 18
34. The Business of Artificial Intelligence [WWW Document]. Harvard Business Review (2017). https://hbr.org/2017/07/the-business-of-artificial-intelligence. Accessed 10 Apr 18

35. Mytnyk, B., Tkachyk, O., Shakhovska, N., Fedushko, S., Syerov, Y.: Application of artificial intelligence for fraudulent banking operations recognition. Big Data Cogn. Comput. **7**(2), 93 (2023). https://doi.org/10.3390/bdcc7020093
36. Uddin, K.M.M., Rahman, N., Rahman, M.M., Dey, S.K.: Artificial intelligence based domotics using multimodal security. Int. J. Intell. Syst. Appl. (IJISA) **15**(3), 44–55 (2023). https://doi.org/10.5815/ijisa.2023.03.04

Historiographical Myth or Proven Fact? The Discourse Around the So-Called Marian Reforms in the Works of Contemporary Researchers

Mykola Oliynyk, Olga Stadnyk, Lidiia Piskozub, Andriy Zachepa, and Oksana Mykytyuk

Abstract The article analyzes the state of research on the so-called military reform of Gaius Marius in modern historiography. By analyzing the works of modern researchers of the Roman army, an attempt is made to highlight the most controversial issues of the problem. In particular, whether the reform itself took place in space and time and whether it was Marius who led to the emergence of a professional army in Ancient Rome. We also drew attention to the incompleteness of the discussion around the reform initiatives of the Arpinatus, as debates are still ongoing about the transformation of the Roman army into a professional one by Marius. It was also noted that among the researchers of the republican army—French, British, American, Canadian, and Polish-there are those who claim that the "Marian Reform" is a "historiographical myth." There are also those who stubbornly and categorically continue to prove the existence of the "reform", despite the considerable amount of refuted evidence provided in the works of Emilio Gabba, Jacques Armand, John Rich, and Peter Brunt, which have already become classics. Some of the contemporary researchers have evolved their views on this issue, possibly after reading the work of the above scholars. We have not only attempted to analyze the works of the last twenty years, but also to show some of the basic principles on which the vision of a new view of what is called "Gaius Marius' military reform" is based. The authors of the publication outline several directions of vision of the so-called Gaius Marius reform in modern antiquity—from the complete rejection of the existence of the "reform" and the initiatives of the Arpinatus in the military sphere to the vision

M. Oliynyk (✉) · O. Stadnyk
Department of Information, Library, Archival Affairs and Foreign Languages, Ukrainian Academy of Printing, Pid Goloskom 19, 790 20, Lviv, Ukraine
e-mail: kolja4791@gmail.com

L. Piskozub
Department of Media Communications, Ukrainian Academy of Printing, Pid Goloskom 19, 790 20, Lviv, Ukraine

A. Zachepa · O. Mykytyuk
Department of Social and Humanitarian Sciences, Ukrainian Academy of Printing, Pid Goloskom 19, 790 20, Lviv, Ukraine

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2024

P. Štarchoň et al. (eds.), *Data-Centric Business and Applications*, Lecture Notes on Data Engineering and Communications Technologies 213,
https://doi.org/10.1007/978-3-031-62213-7_4

of it as a complex phenomenon (with technical, tactical and social components), a turning point in the military and political history of ancient Rome and an indisputable, already proven fact.

Keywords Gaius Marius · Military reform · Ancient Rome · Professional army · Republican army · Historiography

1 Introduction

The reforms of Gaius Marius in the military sphere first became known from the works of German scholars of the first half of the nineteenth century. They formed the concept of "Gaius Marius reforms" in scientific terms, based on the decision of the Arpinatus in 107 B.C. to recruit proletarians into the army and rejected the traditional conscription based on property. As early as 1846, Christian Conrad Ludwig Lange outlined what is still inextricably linked to the Gaius Marius: the creation of a professional army, a cohort legion, the abolition of the civilian cavalry, the formation of the *auxilia*, and other innovations [1]. In 1886, another German historian, Wilhelm Wotsch, published a work on Marius as a reformer of the Roman army [2]. The problem is that most modern researchers repeat the conclusions of both these historians and their predecessors or successors [3, 4]. And this is despite the convincing arguments of leading scholars of our time who have carried out an in-depth analysis of all available sources to deconstruct this "historiographical myth". The supporters of the "reform" simply ignore these publications, which can only emphasize the scientific value of the latter and avoid public discussions about their assumptions on this topic. We will try to approach this problem in more detail, focusing on the most recent works of both those who support the existence of the reforms and those who deny the reformist initiatives of Marius.

1.1 Analysis of Recent Research and Publications

A detailed analysis of the historiography related to the topic of our study was carried out by François Cadiou in his latest monograph "L'Armée imaginaire. Les soldats prolétaires dans les légions romaines au dernier siècle de la République" (2018). However, the French scholar focused on the socio-political aspect of the problem, ignoring the technical and tactical components of the "reform". For the first time, we analyzed the works on the late republican army and the "Marian reforms" not only by studying articles and monographs by Western European and American scholars but also by involving historians of Central and Eastern Europe in the analysis.

1.2 Methodology of Historiographical Research

As for the research methods, we used the methods of objectivity, historiographical analysis and synthesis, typologization, and the comparative method. We have also used special methods of certain branches of historical science, in particular source studies.

The method of objectivity, in our opinion, is the most problematic in this list, because of the specifics of the historiographical phenomenon we are studying, in particular, the dominance of the subjective factor (the actual personality of the author of the text under study), makes it difficult to achieve absolute objectivity in the analysis of the works under study.

The method of historiographical analysis and synthesis is the most used in our study since it is based on a critical examination of the scientific work of scholars with a comparison of their results and the establishment of the peculiarities of their vision of the topic.

The method of typologization presupposes the existence of a set of certain features inherent in a particular historical phenomenon (in particular, here, the researchers' vision of the so-called "Marian Reform"). By combining the facts, we are studying (recruitment in 107 BC *capite censi*, as well as some technical, tactical, and social components attributed to Gaius Marius' initiatives) into a process, we get a kind of matrix to study and describe. In our context, we have a multifaceted view of the existence of "military reform."

The comparative method allows us to compare different visions of the "reform" that have changed over time, even in a relatively short time, here—over the past twenty years.

The source study method is related to the analysis of the works of ancient authors that mention the causes and course of the "reform," in particular, the peculiarities of reading ancient texts by modern researchers and their interpretation of certain fragments of Sallust, Aulus Gellius, Valerius Maximus, Plutarch, and others.

2 Coverage of the "Gaius Marius Reform" in Collective Monographs

Before we begin to analyze the problem under study, we note that the key point of the vast majority of works listed in our bibliography is the recruitment of landless *capite censi* in 107 BC [5], and the authors see the reason for this event in the demographic crisis that swept the Roman state in the second century BC. Another important element of these works for us is the fact that historians raise the issue of the emergence of a professional army, and more specifically, whether Marius gave impetus to this process or whether certain elements of it (voluntariness, long

service, etc.) had already existed since the third century BC. Let us now turn to the bibliography of the "reform".

2.1 «A Companion to the Roman Republic» (2006) and «A Companion to the Roman Army» (2007)

Let us first consider some parts of three collective monographs that have become a kind of reference book in which well-known contemporary historians have accumulated all the previous information on the history of the Roman army. Each of them personally contributed novelty and original concepts to the vision of the functioning of the military machine of ancient Rome, in particular the Republican period. These are "A Companion to the Roman Republic" (2006), "A Companion to the Roman Army" (2007), and "The Cambridge History of Greek and Roman Warfare" (2007). François Cadiou called the last two of them "…great syntheses of military history", and the information about the *dilectus* of 107 BC—a formalization of previous studies of this event [5].

In his part of the monograph "A Companion to the Roman Republic"—"Army and Society", Paul Erdkamp write that the conditions of long service turned citizens into professionals in military affairs, and the troops were mainly composed of volunteers [6]. The scientist's approach to the actions of Marius in 107 BC is quite controversial. In one place, P. Erdkamp argues that the Arpinate practically abolished the property requirement and the legions became more homogeneous, and their connection with Rome became weaker and weaker. The researcher writes that "Marius is probably to be credited with reorganizing the legions, as a result of which all distinctions of property or age were abolished" [6]. The commander transformed the legion into a unified combat unit—it began to be staffed exclusively by heavy infantry. The legion also received its own symbol, the silver eagle. He also writes about paying for equipment for poor recruits from the state treasury. Then, on the same page, the Dutch historian continues, as if contradicting himself: "This was not as great an innovation as it might seem: the property qualifications had been reduced regularly during the past century" [6]. From this, it can be understood that P. Erdkamp does not see anything special and unusual in the recruitment of the poor in 107 BC. In his opinion, Marius considered it necessary to abolish the property qualification altogether, which had already been significantly reduced to the insignificant amount of 1500 asses. This is confirmed by the researcher in another work, where he writes that the property qualification at the end of the second century BC was quite low and the owners of the smallest farms had access to service in the legions [7].

In the seventh part of this collective work, "Controversies", Robert Morstein-Marks and Nathan Rosenstein address the problem of the property test. They write that: "…Marius decisively broke the link between wealth and military service by enrolling the property-less poor (*proletarii*) for his Jugurthan campaign of 107" [8]. This, according to the researchers, opens the way to the formation of an army of very

poor citizens who served mainly to improve their financial situation and hoped for the success of their commanders, not the decisions of the Senate [8]. However, they clarify that it is not known whether poor and landless citizens actually constituted the majority of the military mass of the Late Republic. According to them, no army that took part in the civil wars of the first century BC was disloyal to the republic and referring to the authoritative work of P. Brunt [9], they reject the existence of "client armies" [8]. This means that Marius initiative to recruit the poor, if it did take place, did not achieve its goal, because the sources do not contain any information on this matter,—the scholars write [8].

As in the previous monograph, the authors of the next monograph, "A Companion to the Roman Army" (2007), share almost the same vision of the "reform of Marius". Pierre Cagniart speaks of Marius as the founder of the professional army. The soldiers recruited by him in 107 BC were motivated by the hope that they would receive land grants after the Jugurthian War (112 BC–105 BC). And their hopes were not in vain—in addition to land in Africa and Northern Italy, they also received a considerable financial reward. A French scholar argues that this precedent of Marius became a motivational impetus for military service, turning a Roman from a militia soldier into a mercenary. Also, the Roman soldier began to realize that from now on, his welfare after the end of his service would depend on the ability of the commander to provide it. And this is the basis of a professional army [10]. P. Cagniart does not agree with the thesis that Marius introduced the cohort but notes the important role of the Arpinatus in improving the mobility of the legion and the training of soldiers [10]. The researcher writes directly about the "military reforms carried out by Marius" without going into much detail about the emergence of this "reform" [10]. He only notes that after the gradual lowering of the property requirement in the second century BC, Marius abandoned it when recruiting recruits [10].

Luuk de Ligt supports E. Gabba's [11] position on the significant "proletarianization" of the legions long before the emergence of Marius in the military and political field [11, 12]. But he also points out the mistake of the Italian historian, who interpreted this trend as a consequence of a constant demographic decline. Most likely, L. de Ligt writes: "…the gradual proletarianization of the legions was caused by a continuous demographic expansion that reduced an ever-growing number of Roman citizens to poverty during the second half of the second century BC" [11]. This also explains the systematic reduction of the property requirement—from 4000 to 1500 asses [11]. By "demographic expansion" is meant a "demographic explosion" that led to the above-mentioned "proletarianization". In his later work, the scientist confirms this thesis, noting the lack of reliable information about the social origin of the recruited legionaries in 107 BC. Reference [13] and the existence of many weaknesses associated with the traditional interpretation of the military reform of 107 BC [13]. L. de Ligt was referring to the lack of data in the few sources not only about the reform as a phenomenon that took place, but also the absence of certain material in them that would shed more light on the social status and age of the soldiers recruited by Marius. He devoted a part of his fundamental monograph to these problems, as well as to the impact of demography on military service [13].

An interesting conclusion about the professionalism of Marian's soldiers is made by another Dutch historian, Lucas de Blois. He writes: "Marius' mules, as his soldiers were called, did not constitute a professional mercenary army, but they became nearly as good as professionals by experiencing one military campaign after the other, either in Northern Africa, against the Numidians, or against invading Germanic tribes in Southern Gaul and the Po Valley" [14]. According to the Dutch scholar, Caesar's army became "near-professional" between 58 and 51 BC, i.e. during the Gallic campaigns [14]. We can see that in seven years he has not changed his views on the Marian army, because in 2000 a professor at the Catholic University of Nijmegen expressed the same views [15]. Summarizing the republican army, L. de Blois wrote about it as "near professionals" [14, 15] (see above his view of Caesar's army in 2007—author's note). Some citizens who served in these armies for a long time turned into a cohesive, homogeneous group of society [14]. Here, L. de Blois seems to hint at the emergence of a corporate military spirit—*esprit de corps*—in the first century BC, which appeared in the time of Caesar [16–18]. The scholar also distinguishes between the military professionalism of mercenaries and the professionalism of volunteers, attributing the latter to the military of the late Republic [15].

2.2 *«The Cambridge History of Greek and Roman Warfare» (2007) and «The Encyclopedia of the Roman Army» (2015)*

In "The Cambridge History of Greek and Roman Warfare" (2007), information about the "Gaius Marius Reform" is contained in two subsections—"Military forces" by Boris Rankov and "War and society" by Colin Adams. In the first, the professor of Royal Holloway University of London is cautious about the statement about Marius as the sole creator of the reform, agreeing that the Arpinatus only consolidated in practice those technical and tactical innovations in the military sphere that had taken place in previous years, or even centuries (the emergence of cohort tactics, "Marius' mules", the improvement of the *pilum*, and *capite censi* recruitment) [19]. C. Adams has a similar vision of Marius' actions, however, somewhat more radical than his colleague. He writes that the Roman commander, "…according to our sources, was the first military commander to open the army to landless recruits (*capite censi*), although it is equally likely that he was merely formalizing an existing unofficial practice" [20]. The British historian confirms the existence of "…the military reform of Marius in 107 BC, which abolished the property qualification for military service", but recognizes the more significant consequences for Roman military affairs of the Social War of 91–87 BC [20]. According to C. Adams, it was she, not the Marian reforms, who effectively ended the distinction between Roman and allied contingents by extending citizenship to the entire Italian peninsula [20]. The researcher emphasizes caution in interpreting the sources on the actions of Marius, especially the work of Sallust, because, in his opinion, they are "Anti-Marian sources" and "for

they are loaded with class bias" [20]. Thus, both researchers, although recognizing some innovations in the army as the merit of Marius' predecessors, confirm Marius' contribution as a reformer to the improvement of the army of republican Rome.

The authors of reference works are mostly inclined to believe in the existence of a "reform". We will analyze only the most popular ones. For example, Patricia Southern avoids the phrase "Gaius Marius' military reform". She does not directly refer to him as a reformer but describes him as a prominent military figure who contributed significantly to implementing some innovations. The researcher is cautious about the very fact that Marius carried out some "reforms," emphasizing that: "…the fine details of the reorganization and how it was carried out are not known" [21, p. 95]. In particular, this concerns the transformation of the manipulative legion into a cohort legion. In addition, P. Southern mentions introducing a three-line system of building a legion on the battlefield and the emergence of the eagle as a symbol and the most important insignia of the largest military unit in Rome. It was in the time of Marius that the legions received, according to P. Southern, "strong corporate identity" [21].

Adrian Goldsworthy supports the fact that Marius carried out the reform in 107 BC while rejecting the long evolutionary path of the Roman army from conscription to professionalism [22, 23]. He considers it incorrect to downplay the importance of the reform by modern historians, and he calls the Roman army before Marius semi-professional (see the above judgment of L. de Blois—author's note). At the same time, A. Goldsworthy gives an example of the career of the centurion Spurius Ligustinus, who was rather a semi-professional military than a professional soldier [22]. According to the historian, the traditional view of the results of the "reform of Marius" is too simplistic, especially concerning the emergence of "private" or "client" armies in the first century BC. He does not support the conclusions of those researchers who believed that during the years of active military activity of the Arpinatus there were no sudden changes in the Roman army [22]. Like L. de Blois, A. Goldsworthy also proves the fact that the Roman army became professional in the time of Julius Caesar [23].

In 2015, the three-volume "The encyclopedia of the Roman army" was published. It should be noted that no articles are devoted to the "reforms of Marius," and the material about the Arpinatus himself, presented by Arthur Keaveney in the second volume, does not contain information about Marius as a reformer. However, the persistence of the model of the problem we have outlined, that is, the vision of this "reform" as a phenomenon, is also evident in this collective work. For example, in the chapter on recruitment during the Republic, Stefano Magnani writes that thanks to Maria, the poorest sections of society were given the opportunity for career growth and social advancement, all thanks to access to military service. It was from such young people, the Italian scholar argues, that professional military personnel was later formed [24].

3 The "Reform of Gaius Marius" in the Works on the Military Affairs of Republican Rome

3.1 Ross Cowan, Michael Sage, and Arthur Keaveney's Views on the "Reform"

In quite a few works on the analysis of the military affairs of Republican Rome and the socio-political role of the army, we find different views of historians in terms of the vision of "reform". For example, Ross Cowan, a researcher of ancient Roman military affairs, avoids the definition of "Marian reform" and instead uses "so-called military reforms of Marius" [25]. At the same time, he does not deny the general's participation in the innovations traditionally attributed to Arpinatus [25]. As for the recruitment of *capite censi* in 107 BC and 104 BC, the military historian does not see anything unusual in these steps by Marius. R. Cowan argues that some researchers misinterpret the military commander's actions during *supplementum* and that he allegedly abolished the property qualification. In fact, only a small number of rural plebs and the urban poor were recruited to support his candidacy for the consulship. The bulk of Marius' army then consisted of *adsidui*, peasants from the outskirts of Rome and Arpinum [25].

Oleksandr Makhlayuk argues that many modern researchers are not inclined to exaggerate the radical step taken by Marius in 107 BC (meaning the lowering of the property requirement—author's note). According to the scholar, the additional recruitment of troops by Marius was of isolated importance. It was only in retrospect that it became clear that an army of poor citizens could become a tool in the hands of commanders who sought sole power [16]. This, allegedly, can explain the attacks on Mary by ancient authors (*Aul. Gell. 16.10.4; Iul. Exup. 2.9-12; Flor. 2.3.1; Sall. Iug. 86. 2-3; Plut. Mar. 9.1; Quint. Decl. 3.5*). At the same time, O. Mahlayuk emphasizes that the proletarianization of the army did not become total, because even in the late republican period a large number of legionnaires came from well-to-do families (*Cic. Att. 8.12; Dio Cass. 48.9.3; Plut. Crass. 10.2*) [9, 16, 26].

Michael Sage, author of a new study on the development of the republican army, does not consider Marius a reformer either [27]. But, in his opinion, Marius set a precedent for the development of a semi-professional army by allowing numerous volunteers and the poor to serve, which became a common practice [27]. At the same time, the American historian does not reject the term "Marius' reforms", arguing that the act of the Arpinatus, according to sources (see above—author's note), meant a break with the previous practice of recruitment [27]. Although the ancient authors may have exaggerated its negative consequences, Marius began the process of gradually breaking the ties between the central government [28, 29] and the army [27].

In his work "The Army in the Roman Revolution" (2007), A. Keavney does not see any revolutionary nature in the actions of Marius in the late second century BC, because the commander, in addition to recruiting *capite censi*, also recruited a

significant number of *adsidui* [30]. Unlike M. Sage, A. Keavney argues that Marius did not seek to set any precedent or create any far-reaching changes in recruitment methods. Rather, he, faced with the problem of recruitment, solved it in a way known to us from the sources, which was sporadic. After all, the traditional conscription (*dilectus*) and compulsory enlistment (*conscriptio*) remained in place and were not canceled. A property qualification was also applied to potential recruits [30]. The Irish scholar believed that Marius' goals were not very ambitious at the time, and he was restrained by "the conditions of the time in which he lived" in contrast to the triumvirs of the first century BC, who "pursued greater and more destructive goals" [30].

3.2 The Vision of Jeremiah McCall and Michael Taylor

Jeremiah McCall, an author of a monograph on the cavalry of Republican Rome, also rejects the existence of the so-called "reform". He argues that no serious military reform could have been implemented without the support of the changing senior officers and the central government [31–33], in particular the Senate. Since this researcher specializes in the study of cavalry, he pays more attention to the problem of the existence of cavalry among the citizens after Marius. J. McCall does not support the claims of some researchers regarding the abolition of the Equestrian cavalry. The dissolution of such an elite military unit would have required a consensus among the senators, or at least a majority of the nobility. Such a consensus might not have been possible, given the tense relationship between Marius and the nobiles [34].

In a new study on the tactical reforms of the late Republican Roman army, Michael Taylor categorically rejects the existence of the "Marian reform". All the organizational and tactical changes that took place under that name were not due to the creator of the eponymous "reform" but to the infusion of the *socii* into the legion during the first half of the first century BC. The organizational and tactical component of what is called the "Marian reforms", according to M. Taylor, was the result of the influence of allied contingents (*cohorts*), especially after the Social War of 91–87 BC. The final evolution of the legion, i.e. its transformation from a maniple to a cohort one, was completed in the middle of the first century BC, i.e. in the time of Caesar [35].

4 "Marian Reforms" in Generalized Works and Biographical Studies

4.1 "Reform" in General Works on the History of Ancient Rome

The views of the authors of general works on the history of republican Rome are opposite in their vision of "reform". Michael Crawford writes about two different approaches to "changing the way of recruiting" [36]. The first, which is described by the tradition unfavorable to Marius, claims that he did it to gain popularity. The second, that of his defenders, emphasizes that the new recruitment system was very democratic and pushed its introduction from 107 to 104 BC. In this way, the proponents of this approach show that the Germanic invasion was more threatening to Rome than the Jugurtha and that the reform of recruitment this year is more likely [36]. The historian himself supports the thesis that Marius abolished the recruitment system based on the property status of the recruit and the disappearance of lightly armed (*veliti*) and cavalry (*equites*) from the legion [36].

Klaus Bringmann sees Marius as a reformer of the technical and tactical components of the Roman army and does not mention the social component in his work. Like M. Crawford, the scholar believes that the Roman army was reorganized in Southern Gaul in 104 BC, i.e. during the Cimbrian War. The reorganization consisted of unified weapons and cohort formation [37]. Although K. Bringmann writes about these innovations, he avoids the term "military reform" in his work, mentioning only the above components.

Similar to the opinion of K. Bringmann are the conclusions of the famous Polish antic scholar Adam Ziółkowski. He does not see any turning point in Marius recruitment of *capite censi* and, referring to the authoritative work of John Rich, speaks of this event as a "one-time occurrence" [26, 38]. Instead, the Arpinat, according to the researcher, was an innovator in the field of reforming weapons, tactics, and training. These innovations were implemented during his consulship of 104–101 BC and turned the legion into the most advanced infantry formation in history, including the creation of firearms [39].

A researcher of the army's influence on the Roman political system and society, adheres to the old model of the so-called "reform" [16]. Agreeing that the "military reform of Gaius Marius" was not the first step in the evolution of the Roman army, he confidently asserts that a "real army of professionals" was created at the end of the second century BC without particularly analyzing the ancient sources. Researchers argue in a similar vein, proving that military reform is attributed to Gaius Marius by ancient tradition, although the sources do not contain information about certain reforms. The researcher mistakenly believes that the army ceases to serve the republic, and the state's interests fade into the background, promoting an outdated thesis about violating the traditional connection between the concept of "warrior-citizen". The historian does not use the vast body of modern historiography, which deals with

the problem of the relationship between legionaries and the higher command and authorities in all aspects. One gets the impression that she is far from knowing the new theoretical and methodological approaches of modern antiquities to the political realities of the Roman Republic.

4.2 "Military Reform" in the Biographies of Gaius Marius

Unlike the prominent military and political figures of the second and first centuries BCE, to whom a large number of biographies are devoted, Marius has not received similar attention. Among the few biographies of the Arpinatus over the past two decades, we will highlight two where the "reform" is given considerable attention. The first one, by the young German historian Marcel Labitzke, analyzes ancient sources rather one-sidedly and rejects the criticisms of contemporary researchers regarding the "military reform" [40, pp. 132–135]. Judging by the list of references used to write this part of his biography, M. Labitzke ignored the works of modern antic studies scholars who have studied the problem (the only exceptions were the works of J. Rich and P. Brant—author's note) [40, p. 135]. This, by the way, is characteristic of the works of those researchers who are supporters of the existence of the "reform". M. Labitzke focused mainly on analyzing the works of German-speaking historians of the second half of the nineteenth century and the first half of the twentieth century and some few contemporary authors [4, 37, 41], the number of which is also quite limited for such a broad topic [40]. Using the outdated view of Theodor Mommsen on the professionalization and proletarianization of the army, the author emphasizes that the measures of Marius changed the Roman military system for a long time. Like some other researchers (see above—author's note), the historian repeats the thesis that the admission of the poor to the ranks of the legions was a solution to the problem of recruitment, which was a turning point in the transformation of the army into a professional one [40]. It is known that in the first century BC legions were still recruited from wealthy citizens (see above—author's note) [5, 9, 30, 42]. Federico Santangelo is more restrained in his conclusions about the "reform", he does not consider the set of 107 BC a "great reform" and urges not to overestimate its importance [43]. He writes that it was a well-thought-out and ambitious measure by Maria, implemented by innovative methods to satisfy her interests [42, 43].

Like M. Labitzke, Andrii Koval's dissertation [44] speaks of the "reform of Marius" as the completion of the process of proletarianization of the army. Of course, he did not set out to investigate more deeply the reasons for the actions of the Arpinatus in 107 BC and the historiography of the "reform" problem, but at his discretion interprets passages from some sources, for example, from the work of Lawrence Keppie [44]. A. Koval writes about the long-term consequences of the "professionalization of the Roman army" that led to the separation of the interests of the army and the state, missing further remarks of the Scottish historian. L. Keppie argues that Marius activities did not lead to any fundamental revision or reform of the conditions of military service. Throughout the first century BCE, the norm for the

participation of conscripts aged 16 to 46 in a maximum of 16 campaigns continued to apply, i.e., militia recruitment remained in place [45]. However, succumbing to the already established tradition, A. Koval repeats the thesis about "the reform of Marius in 107 BC" [44].

We see the same conclusions in the works of Andriy Pilkevych. Strangely, he writes that: "…for the first time in Roman history, Marius proposed to abandon the principle of censorship in the recruitment of legions, allowing all citizens to join the army" [46]. It is known that this practice has already been used in the history of the Republic (*Cass. Hem. Frg. 24; Liv. 22.57.3-5, 23.32.19, 25.5.6, 25.20.4, 25.22.3-4, 27.38.8, 27.38.10, 28.10.11, 28.46.13; Oros. 4.1.3; Aug. De civ. Dei. 3.17; Ennius. Fragm. 6, 174–178*) [17, 26, 47]. Moreover, information about this is contained in the work of P. Brant, which is mentioned in the historiography of the study [46]. But, judging by the above quote, A. Pilkievych did not study "Italian Manpower" very carefully [9]. In his subsequent works, the researcher continues to exaggerate the importance of *supplementum* of the Marius, focusing on the property status of Roman citizens [48, 49]. This seems a bit strange, because again, in the list of references used by the historian, we see the works of researchers who have done the most to refute the long-established claims about the recruitment of a significant number of *capite censi* [49]. We are talking about the already mentioned P. Brant and J. Rich. The latter, for example, proves that during the recruitment of 107 BC only 3000 soldiers were additionally recruited out of the total number, i.e., out of 8000 legionaries who served in Numidia until the end of the war with Jugurtha. Of these additional recruits, according to J. Rich, only a part could be classified as poor, and the actions of Marius were only "an isolated incident" [26].

5 The "Military Reform of Marius" as an Object of Study

5.1 "Reform" in the Research of East European Historians

Let's move on to analyze the works of those researchers who aimed at a broader analysis of the so-called "Mariu's military reform". For example, Ivan Merkulov, unlike A. Pilkievych, approaches the study of this topic more thoroughly. He, along with O. Makhlayuk, is one of the first researchers in Eastern Europe to criticize traditional approaches to the vision of the so-called "reform". However, some of I. Merkulov's conclusions are ambiguous. On the one hand, this historian correctly summarizes the myth-making of some researchers who interpret Marius as the author of the definition and establishment of the terms of military service. In fact, the attribution of this innovation to her is not confirmed by historical sources [50]. On the other hand, he does not deny that Arpinatus carried out some reforms, particularly in the socio-political sphere. Here he means weakening the influence of nobility by democratizing the Senate with the infusion of *homines novi*. The latter were to be representatives of the wealthy part of the horsemen. It was a centurial reform with

elements of democratization [50]. Without naming Marius of the "military reform" [50]. Also, A. Merkulov does not abandon the term "Marian reform," but, as we have already noted, he manipulates the facts given in the sources [51, 52]. In particular, this applies to the interpretation of passages that referred to the unification of weapons, the "proletarian" origin of Spurius Ligustinus, and the introduction of the eagle as a symbol of the legion [9]. Regarding the admission of the poor to the ranks of the legions before the "reform" and the emergence of soldiering before the Marian period.

Like the previous researcher, Michał Norbert Faszcza belongs to the cohort of those who prove the falsity of the existence of "military reform". It is also worth noting that the Polish researcher has undergone a certain evolution in his views on "reform". Initially, he perceived it as an event that took place in history, noting that: "…the set of reforms implemented through him (i.e., Marius—author's note) led to the creation of a professional army that successfully replaced the previous militia" [53]. Two years later, M. Faszcza wrote about Augustus' reforms as having: "…turned the legions into a fully professional army" [54]. In the same year, he published the article "Marian reforms" and their real authors" (2012), in which the historian refutes the myth of Marius the sole initiator of the creation of a professional army, which is widespread, including Polish historiography [55]. M. Faszcza, based on a significant source base, analyzed all the components of the so-called "reform of Marius", identifying those who, in addition to Marius, contributed to the reorganization of the legions during the II-I centuries BC, without rejecting the role of the Arpinatus in these processes [55]. Exploring the reasons for the emergence of this "historiographic myth", he writes that "…we are dealing with a historiographic construct based on the interpretations of some researchers, not with an indisputable historical fact" [1]. M. Faszcza concludes that the misconception of the broad reformist activity of Marius is usually observed in the works of military history researchers [1]. The latter, in turn, mostly ignore works on demography, which explain that the republic had no problems finding the necessary number of recruits. Rome has always had human resources at its disposal, which provided it with an overwhelming advantage in a conflict with any enemy [1]. And Marius acted in such circumstances and under such conditions that it was impossible to step to realize what is attributed to him [1]. However, the Polish researcher did not abandon his conclusions about the beginnings of the professionalization of the Roman army, starting in the third century BC, the role of Marius in consolidating the cohort structure of the legion and the introduction of its symbol, the eagle [1, 54–56]. We should also add that we have also to some extent gone through the evolution of views on the "reform"—from perceiving its existence as an indisputable fact to revising this position, changing the vision of some of the initiatives of Marius and whether they took place in history at all [52, 57]. A detailed familiarization with the source base and extensive bibliography of the topic helped us to better understand the issue and encouraged us to continue researching this problem. We believe that this was not a full-fledged military reform, but only some of Marius' reform initiatives, which concerned several technical innovations.

Returning to the analysis of the Polish researcher's work, he, like the aforementioned I. Merkulov sometimes manipulates facts [58]. M. Faszcza argues that the

involvement of *capite censi* in the ranks of the Roman army took place long before the military reform, in the third century BC [55]. After analyzing the source, we find out that Livy in his work actually mentions the forced recruitment of freed slaves and underage citizens into the legions (*Liv. 22.57.11, 23.32.1, 25.5.7*), but not *capite censi*, which are not mentioned in these references to "*Ab Urbe conditia*" at all [52]. M. Faszcza repeats the same mistake in his dissertation [17]. In it, he concludes: "The recruitment of *capite censi*, carried out by Marius in 107, did not become a precedent in the history of the Roman Republic, as such a decision was sporadically resorted to in previous years. Marius did not abolish the general obligation to perform military service, and the mobilization of the proletarians remained a rare event for a long time. Therefore, his role as a reformer in this area is not based on facts… Marius' merit, however, was the consolidation of… cohorts, the introduction of legionary eagles, and the reorganization of camps. It should be remembered that the so-called reforms of Marius were another important stage of change that led to the professionalization of the Roman army, but were not a one-time initiative" [17].

In 2019, the second, somewhat expanded edition of the book (the first appeared in 2009—author's note) by Andrzej Graczkowski "On Marian military reform. The birth and development of the professional army in ancient Rome (second-first century BC)" [59]. His study resembles the work of J. Harmand in terms of the concept of content and presentation of the material (perhaps the Polish author borrowed it—author's note), with the only difference being that the Polish historian paid more attention to the initiatives of Marius, and J. Harmand—to the post-Marian army with an emphasis on the period of Julius Caesar [5, 18, 59]. The peculiarity of its content is the unequivocal vision of the "reform of Marius" as "…a cornerstone" and "…a turning point in the extended chain of transformations" of the Roman army [59]. A. Graczkowski agrees that the professionalization of the Roman army did not happen suddenly, but continued gradually, having its many creators [59]. In his views on the reform, the Polish historian tries to adhere to the "golden mean" but at the same time goes to extremes, arguing that it was Marius who introduced voluntary service in the Roman army. He considers it a mistake to prove that the militia continued to function until Augustus' reforms [59]. Most likely, A. Graczkowski was not familiar with the works that refute the thesis of the predominance of volunteers in the ranks of the legions until the end of the first century B.C. [5, 13, 60, 61]. Even the presence in the list of references of the already mentioned work by J. Harmand and more than one work by E. Gabba and P. Brant [59], who contributed to the refutation of the myth of the "professional army of volunteers," did not force A. Graczkowski to draw certain conclusions about the "initiatives of Marius." The historian's conclusions about the reasons for the implementation of the "reform" also seem strange. One of them is that Marius allegedly introduced it as a result of the "crisis of the traditional civilian army" due to the "demographic crisis" [59]. But, looking through the bibliography of the book, the position of A. Graczkowski's position becomes clear. He either did not specifically use the work of authoritative researchers on this issue [11, 13], including Polish ones [62], or did not make his conclusions, avoiding uncomfortable conventions that would level the author's vision of the book's concept. The historian used mainly secondary Polish-language literature, often of a popular science nature

and by authors of the second half of the nineteenth and first half of the twentieth centuries, while avoiding newer authoritative works that would address the problem of "reform." This neglect makes A. Graczkowski's study incomplete, since neglecting the socio-economic component of the problem leads to a one-sided interpretation of the events of 107 BC. As M. Faszcza rightly notes, the recruitment crisis of the time did not cover the entire army stationed in Numidia and recruited in the traditional way (*dilectus*) [63]. Marius only conducted an additional recruitment (*supplementum*), which was not something unique or revolutionary, as some authors, including A. Graczkowski, would like to see (or describe). However, in our opinion, M. Faszcza criticizes his compatriot too harshly, perhaps even unfairly [63]. After all, A. Graczkowski's book does not claim to be scientific, and the publishing house where it was published is engaged in publishing literature that popularizes military history and does not publish scientific publications. Although, even here M. Faszcza does not recommend it even to those who are just beginning their acquaintance with the military history of Republican Rome [63, p. 203]. He reproaches A. Graczkowski for his reluctance to consult with experts on the history of the Roman Republic and expresses the hope that such "…simplified perception of the military activities of Marius will no longer appear in Polish publications, once and for all giving way to more balanced research" [63].

Alexei Kozlenko calls the "Marian reform" an "artificial concept that unites phenomena and processes that have been developing for a long time" [47]. In his research, he dates the process of professionalization of the Roman army to the second century BC—first century BC and does not tie it to one person. The Belarusian researcher criticizes the idea that Marius abolished the manipular order of formation of the legions and replaced it with a cohort order. Without citing any sources, he writes that the division into maniple and centuria remained in place during the first century BC—third century AD and no tactical changes occurred at that time [47]. O. Kozlenko summarizes that "…although Marius played an active role in the development of reform processes, he did not make active reforms that could force or weaken their course. Therefore, they can hardly be directly associated with his name" [47].

Historian Zhyvko Zhekov takes a more thorough approach to this problem. He notes that in modern historiography there are two hypotheses regarding the transformation of conscripts into professional troops. According to the first, the main merit in this process belongs to Gaius Marius, who reformed the legions. The opposite hypothesis is that the Arpinatus did not reform them and they gradually changed under the influence of various objective factors. These problems, according to Zh. Zhekov, give grounds for a new analysis of this controversial topic, which will allow a more detailed understanding of the processes of transformation of the Roman army during the Late Republic [64]. Analyzing the passages of Sallust and Plutarch concerning the recruitment of *capite censi* (*Sall. Iug. 86.2; Plut. Mar. 9.1*), the Bulgarian scholar suggested that the ancient authors aimed to discredit Marius as a violator of *mos maiorum*, so revered by the Romans. However, this does not mean that the possibility of a set of "head counts" is completely rejected. But even if there were such people among the ranks of the *volones*, their number was relatively small compared to the bulk of recruits recruited traditionally [64]. Zh. Zhekov emphasizes an important detail:

"…Marius recruited the *capite censi*, not the proletariat, as many modern general studies of Roman history indicate" [13, 64]. This is a significant difference, and the scholar explains why. Even before the Arpinatus, the Romans recruited proletarians into the legions if necessary [9, 12]. The first reliable information in the sources about their involvement in military service in the legions dates back to 280 BC when the Romans began recruiting proletarians due to large losses in manpower (*Oros. 4.1.3*) [26]. At the same time, there is no exact data on the recruitment of *capite censi* to the Marius in the sources [11]. This category of the population (meaning *capite censi*—author's note) is mainly associated with the Roman *plebs urbana*. Throughout his political career, Gaius Marius was associated with this stratum of the population and acted as their informal leader. In fact, in his political actions, he relied mainly on the support of the urban plebs, in whose interests most of the laws were passed by his political ally Lucius Apuleius Saturninus, who was active in the period 104 BC–100 BC when the Arpinatus probably first recruited *capite censi* en masse. In this context, such recruitment becomes much more logical and understandable [37, 64]. Thus, Zh. Zhekov concludes that the mass recruitment of *capite censi* took place not in 107 BC, but in 104 BC and did not represent a radical reform of the Roman legions and their recruitment means, but was a one-time event caused by extraordinary circumstances caused by an external threat and the inability to quickly attract the required number of recruits. Like M. Faszcza, Zh. Zhekov tends to see the professionalization of the Roman military as a gradual process that began in the last decades of the Second Punic War and lasted until 27 BC [64]. In the case of the transition to the cohort legion, the introduction of cohorts as the main structural unit, according to Zh. Zhekov, refers to a later stage, or rather after the Social War of 91–87 BC (see above the arguments of C. Adams and M. Taylor; see also our arguments—author's note) [57, 64].

5.2 Christopher Matthew and His View of "Reform"

Christopher Matthew, an unquestioning supporter of the conventional vision of "reform," ignores the conclusions of important publications on the subject, focusing only on traditional views and his own conventions. He first described them in his article "The Enrollment of the *capite censi* by Gaius Marius: A Reappraisal" (2006). C. Matthew begins with the controversial and rather controversial claim that Gaius forever changed the demographic composition of the legions and, consequently, the very nature of the most fundamental aspects of the Roman army with his recruitment process in 107 BC [65]. Well, as in the case of A. Graczkowski, the presence of some important works in the bibliography does not guarantee their thorough study, even with frequent references to them [65]. He criticizes Richard Evans, the author of the biography of Marius, known for his ambiguous attitude to the figure of the Arpinatus, in particular, as a "reformer" [5, 65]. C. Matthew objects to R. Evans that he saw the speed of recruitment by Marius in the recruitment of only a small number of *capite censi*, according to J. Rich's calculations [26]. They, equipped and armed

by the state, could be quickly equipped for war, given the voluntary nature of these citizens' involvement in the ranks of the legions. The Australian researcher rejects this claim because, in his opinion: "…The amount of time required to equip and train those drawn from the lower classes into an effective body of fighting men would be similar, if not longer, than the time required to train recruits drawn from the propertied classes who may have had previous military experience. Therefore, the desire for an expedient end to the African campaign cannot have been Marius' motivation for the enrolment of the *capite censi*" [65, 66]. However, a careful reading of Sallust' text reveals that recruits in Numidia mix with already experienced soldiers, and the ancient author himself does not make a fundamental distinction between *novi milites* and *veteres milites* (*Sall. Iug. 87. 1–3*) [5, 22]. In his article, C. Matthew criticized not only R. Evans, but also J. Rich regarding the wealth of recruits of the late Republican army [65]. After all, as he argues, if the legions consisted mainly of materially well-off individuals, there would have been no debate over land grants for veterans at the turn of the second century BC and the first century BC. [65]. C. Matthew explains the introduction of the eagle as the only insignia of the legion (*Plin. NH. 10.16*) by Marius as contributing to the unity of recruits from different social strata. In addition, the Arpinatus aimed to "…fostered a sense of loyalty to the legion which to some extent replaced the loyalty to the state that was inherent in the propertied pre-Marian soldier" [65]. For some reason, the researcher believes that the Marian army of 104 BC, if it had been a militia of the majority of wealthy *adsidui*, would not have accepted some of the innovations of the Arpinatus, such as the standard in the form of an eagle [65]. It seems that C. Matthew sees the vast majority of legionaries of the Late Republic as pauperized and opposed to the central government.

C. Matthew begins his work on the modification of the *pilum* with a list of five "reforms" introduced by Marian: the *capite censi*, changes in the design of the *pilum*, the introduction of the eagle (*aquila*), the appearance of the *muli Mariani*, and the abandonment of the deployment of the legion by *manipulus* in favor of cohort formation. As for the changes in the design of the Roman dart, the historian believes that they cannot be fully understood without placing them in the historical context of other changes introduced by Arpinatus into the structure of the Roman army [67]. C. Matthew repeats the same in his article on the "mules of Marius". It was Arpinatus that changed the way the legion was recruited, equipped, and organized. The researcher calls the reform of the train "the biggest logistical transformation to the Roman army", which was reduced by the invention of a pole with a crossbar—*furca* and became more mobile due to the transfer of part of the equipment (*sarcina*) to the soldiers' shoulders [52, 57, 68]. Reducing the size of the military convoy also contributed to better protection during the march. If this happened, the legion formed a square (*agmen quadratum*) around the carts with ammunition, forming a circular defense and being able to repel an enemy attack from any direction [57, 68]. C. Matthew also believes that the introduction of the cohort by Marius as the main tactical unit of the legion in 104 BC and the unification of legionary equipment as a result of Marius' opening of the legions to volunteers in 107 BC contributed to the formation of a "new egalitarian Roman military" [68].

In 2010, C. Matthew's was published, where he comprehensively presented his vision of the "reforms" [66]. C. Matthew accuses modern historians of neglecting, ignoring, and inadequately studying "the practical military implications of Marius' reforms", as well as of incomplete, speculative, inconclusive, and misinterpretation of "evidence from a variety of sources" (here, most likely, C. Matthew means ancient sources—author's note) [66]. That is why he set out to revise it again: "…the available evidence to determine the effect that the Marian reforms had on the Roman military system and will evaluate many current academic conventions regarding these reforms to assess their validity" [66]. At the same time, C. Matthew is critical of those who without evidence attribute reforms to Marius in the period between 110 and 30 BC [66]. As in his article on the recruitment of *capite censi* [66], the section of the monograph dealing with this issue contains the same conclusions: "His reform… permanently altered the demographic composition of the legions and, consequently, the very nature of the most fundamental aspects of the Roman military" [66]. C. Matthew considers the recruitment of 107 BC to be the cornerstone of the reform, which had far-reaching consequences for the army. He argues that the recruitment of *capite censi* was a practical innovation aimed at combating the reluctance of the *adsidui* to join the ranks of the legions [66]. Although, a similar thesis was already put forward by Yanir Shohat in 1980, whose monograph is not included in the bibliography of "On the Wings of Eagles…" [5]. C. Matthew discusses with J. Rich the lowering of the property requirement to 1500 asses, agreeing with the discrepancies in the works of ancient authors and the possible damage to their texts over time. At the same time, he puts forward his hypothesis that the aforementioned lowering of the qualification level was due to the impoverishment of the peasants, which is also confirmed by L. de Ligt (contra—R. Morstein-Marx and N. Rosenstein—author's note) [8, 13, 52, 61, 66]. M. Faszcza calls this work by K. Matthew "…a deeply conservative and sometimes controversial booklet", in which he "…first assumed the existence of the reforms of Marius, and then began to associate with them various phenomena that were based on a nineteenth-century hypothesis, the correctness of which was never finally proven…, …simply dismissed the voices of critics of the traditional approach with general statements about the existence of such a position in the literature, without showing any trace of reflection on its foundations" [1, 63]. F. Cadiou is also critical of its author, noting C. Matthew's inattention to the not-very-thorough reading of ancient source texts. The French scholar accuses C. Matthew of generalizing both contemporary works and sources from different periods, in particular from the empire, in which the Australian historian wants to see retrospective evidence of the durability of the innovations introduced by Marius [5, 66]. But should we be so critical of this book? We believe that every researcher has the right to his or her version/assumptions or interpretation of Marius actions in the period 107 BC–104 BC—the only question is whether they support their arguments with relevant sources and the level of analysis of their judgments. Even F. Cadiou, a staunch critic of the "reforms of Marius", believes that C. Matthew's book: "…is an important contribution that puts Marius and his reforms back into their proper perspective in Roman military history", while noting that he does not share this point of view [5].

5.3 *"The Myth of Modern Historiography". Interpreting François Gauthier's "Reform"*

François Gauthier is opposed to C. Matthew in his views on the reform. In his dissertation research, he argues that there was no indication that Marius changed *ex classibus* recruitment, nor was there any law in the sources that suggested it. Troops after Marius did not consist exclusively of volunteers, and *dilectus* did not disappear. It was still frequently used during the first century [60]. There is also no evidence that Marius created a permanent professional army of landless volunteers who would agree to serve for a certain number of years and receive free weapons and armor. Such a system would appear only later, in the period of Augustus [60]. F. Gauthier believes that to attribute the invention of the cohort to Mary since its development within the legion is not clearly defined in the sources, is to make an argument *e silentio* [60]. Even more problematic is the fact that it contradicts all the available evidence that testifies to the existence of cohorts before the Arpinate. The Canadian researcher argues that debating the long-term development of the cohort is a more reasonable and realistic way to interpret the available sources, rather than trying to fit this tactical unit into "some sort of Marian package deal" [60]. F. Gauthier proves that Marius did not create a professional army in permanent service, for which volunteers would have to sign up for a fixed term. Nor did Marius abolish conscription based on property qualifications; he merely enlisted several thousand soldiers to supplement the army that had already been recruited traditionally by his predecessor Metellus. All of this was not institutional, but rather an ad hoc measure by Marius himself, which did not become a rule [42]. Thus, F. Gauthier agrees with the American historian David Potter, who writes that the army of Marius was, in fact, Metellus' army with a *supplementum* (the already mentioned *supplementum*—see above), including recruits with low social status [60]. F. Gauthier concludes that the concept of the "Marian reform" is misleading and should be abandoned. Its whole idea is based on an excessive interpretation of several passages from Plutarch and Sallust. In addition, it fails to capture the tendency for the duration in time. He asks the question: if Marius did create a permanent professional army, why were very large recruitments to form entire armies regularly held throughout the first century BC? Of course, F. Gauthier explains, many soldiers remained in service for years and became professionals, but this was not because the Arpinatus reformed the army. This is because a certain category of citizens could not find work in "peaceful professions" and therefore had to resort to a life of campaigning, but this phenomenon was not widespread in the last century of the republic. It seems too convenient to attribute to Mary many of the changes that later appeared in the Roman army, but it would be wrong to do so unequivocally, based on the fact that the Arpinatus seemed to act contrary to *mos maiorum* [60]. According to F. Gauthier, the commanders of the first century BC did much more to change the rules of army recruitment and financing, especially after the Allied War, and the concept of the "Marian Reform" is a modern myth created by contemporary historiography [60].

F. Gauthier's article, published in 2016, partially repeats one of the chapters of the dissertation described above, but here he focuses more on some of the details of the "reform" attributed to Marius. The Canadian historian continues to argue that "…the Marian Reforms are a myth created by modern historiography" [69]. F. Gauthier questions the introduction of some tactical and technical innovations by the Arpinat, relying on some ambiguity in the sources and their arbitrary interpretation by some researchers of the nineteenth and twentieth centuries [69]. These "reforms", according to the researcher, their significance and consequences, are exaggerated in historiography. "The Roman army did evolve and change; however it was not Marius who transformed it"—writes F. Gauthier. Its transformation into a professional army took place due to the crises of the last century of the Republic—the Social and Civil Wars [69].

5.4 François Cadiou and His "L'Armée Imaginaire"

We conclude our historiographical review with one of the most important works for the analysis of our problem: "The Imaginary Army. Proletarian Soldiers in the Roman Legions in the Last Century of the Republic" (2018). It has already received numerous reviews and comments that emphasize the author's scrupulousness in working with sources and the volume of literature on this topic [5, 41, 70–72]. The author, F. Cadiou, devoted a significant part of the book to the topic of "reform"—more than a hundred pages of text [5]. In this part, the entire first chapter is devoted to the review and analysis of historiography—multifaceted, diverse in content and interpretation of the "Marian reform" as a step towards the proletarianization of the Roman army. The French scholar notes the stability of the traditional model of analysis, "which is tirelessly repeated", namely the mass recruitment of the poorest citizens voluntarily from a certain time and the professionalization of the army as a result of the actions of Marius [5]. F. Cadiou also emphasizes the fact that the study of the late republican army is complicated by several reasons, unlike, for example, the period of the Principate, especially in the last decade [5]. P. Erdkamp also writes about this [6]. If we take into account the entire period of the republic, then compared to other aspects (problems of the state system, social policy, culture, religion), the army is the least studied [5]. F. Cadiou lists a few monographs on the history of the republican army [5]. And among their authors, the "Marian reform" is perhaps the most interesting [5]. With this, F. Cadiou concludes that due to the lack of accurate information in sufficient quantity and statistical data in few sources, it is important not to forget that the economic and social status of the legionary of the republican period could not be determined with the desired accuracy. Any analysis on this topic involves an inevitable part of guesswork and one's interpretations [5]. The scholar, therefore, seems to be preparing the ground for his detailed analysis of Marius actions in 107 B.C., using a large number of sources and literature [5]. He agrees with E. Goldsworthy and C. Wolff about the contribution of the Arpinatus to the transformation of civilian militia into a professional army, but without any exaggeration. After

all, Marius did not create anything fundamentally new and did not abolish what existed before. Similar practices existed before [5, 18, 22, 39, 70]. At the same time, F. Cadiou notes that K. Wolff, like some other researchers, minimizing the reformatory activities of Marius, continues to associate his figure with the idea of a great turn towards professionalism [5]. F. Cadiou concludes the revision of the vision of "reform" in the second half of the twentieth century, "brilliantly launched" in 1949 by E. Gabba. E. Gabba and continued by J. Rich. He writes: "…most historians have overturned the paradigm that had dominated until then. We no longer believe that the *dilectus* of 107 BC was a revolution (a revolutionary act) that more or less rigidly imposed an irreversible evolution (a professional volunteer army). Nowadays, the opposite scheme is preferred: the idea of a simple long-term evolution (in the practice of recruitment) that facilitates gradual steps towards revolution (a professional army that opens the way to the political tilt of the republic towards empire), as emphasized by J. Rich" [5]. The latter notes (and this also applies to modern historiography—author's note) that although some scholars seek to minimize the significance of Marius *capite censi*, they continue to assume that the Arpinate caused lasting changes [26]. As for the sources, a detailed study of those attributed to the initiatives of the Arpinate, as F. Cadiou notes: "…turn out to be much less convincing than this predominant historiographical model suggests. The ancient authors who mentioned the *dilectus* of 107 BC did not associate it with any idea of long-term reforms or with any socioeconomic problems. Thus, the social reading of the episode appears to be an invention of modern historiography" [5]. Despite this, the French scholar believes that Sallust' passage about this recruitment continues to be a certain argument in favor of changes in the recruitment of that time, "…evidence or assumption of the beginning or acceleration of the process of proletarianization of the legions" [5]. As for the hypothesis about the predominant number of poor people in the ranks of the legions, it is not because, as F. Cadiou explains, there were many of them in the Roman Republic, but because they were more motivated to participate in wars [5].

We agree with Claudio Vacanti that the material of the monograph under consideration is complex even for a scholar specializing in the Roman army and institutions of the Roman Republic, as well as innovative and, to some extent, even revolutionary, marking the evolution of traditional views on the allegedly unshakable vision of the position of the Roman army in the late II century BC—I century BC [41]. Sergio Ríos González, a Spanish reviewer of "L'Armée imaginaire…", emphasizes the extraordinary exhaustiveness of information in the bibliography of the problem and its brilliant analysis [70]. S. González is convinced that "L'Armée imaginaire…" will become a reference work and will break the consensus around the seemingly established position of the late republican army. He rightly believes that F. Cadiou's almost 500-page monograph will long stimulate scholars to put forward new arguments in future research on the Republican army [70]. The scholar does not intend to close the debate on this issue and calls on researchers to engage in a public discussion that could put an end to this controversial issue: "…i do not intend to end the debate, but rather to resume it, encouraging new research" [5]. It is also worth noting that F. Cadiou does not have superiority over his opponents in his views on "reform". His monograph does not contain harsh tones concerning those contemporary researchers

who continue to prove the correctness of the "old concept of reform". Unfortunately, the scholar avoided the problem of attribution of technical and tactical changes in the Roman army attributed to Marius, focusing mainly on the analysis of the historiography of the "Marian reform". But the main idea that F. Cadiou wanted to convey to his readers, not only from his monograph but also from the pages of his previous works, is clear: "the military reform of Gaius Marius" is a pseudo-reform and an artificial historiographical problem [73]. Thus, F. Cadiou, as it were, gives an impetus to modern historians to keep going and considers his work a kind of introduction to the discourse. And there is much to work on, because the army of the Late Republic, compared to a large number of studies on the history of the imperial army, is still insufficiently studied [5].

6 Conclusions

To summarize, most studies of the "reforms" are based on the *supplementum* of Marius in 107 BC and his motives for recruiting *capite censi* into the army. As for the tactical, and especially the technical component of the "reform", they have not attracted as much attention as the socioeconomic and political components. Even if there were references to these first components in their works, they were practically all attributed to Arpinatus, especially the technical ones. So, after analyzing the most important, in our opinion, works that would address the problem of Gaius Marius' reform of the Roman army, we can divide modern historiography into certain categories. The first category includes the works of those researchers who continue to prove the existence of the "reforms of Marius" as a fait accompli [10, 24, 40, 49, 59, 65–68]. The second, and largest, group is made up of those who question or reject the reform initiatives of the Arpinate, in particular, the emergence of a professional army. They perceive the additional recruitment of 107 BC as an event of some importance for the development of the Roman army, but not decisive, and agree that Marius introduced some technical innovations [6–8, 12, 14, 15, 18–23, 27, 38, 39, 45, 52, 57]. The third is the supporters of a critical approach to the "Marian reform". They do not see Arpinatus as a reformer of the military system of Ancient Rome, and, according to their arguments, the professional army appeared there only thanks to Augustus' reform [1, 11, 13, 17, 26, 30, 34, 35, 43, 50, 53–56, 60, 63, 64, 69]. We can observe that over the past twenty years, compared to the previous ones, there has been a tendency to reduce the number of publications in which Marius appears as a reformer of the Roman army. Perhaps the reason for this is a more scrupulous reading of the sources or a more thorough elaboration of the historiographical basis of the study. One way or another, the discourse continues, which means that the topic remains relevant and open to discussion.

References

1. Faszcza, M.N.: Marius' reforms, or the long duration of the historiographical myth. Res Historica **51**, 13–42 (2021)
2. Votsch, W.: Cajus Marius als Reformator des römischen Heerwesens, 48 s. Verlag von Carl Babel, Berlin (1886)
3. Morillo, S.: What is Military History? Wiley (2017)
4. Kromayer, J., Veith, G.: Military History of the Greeks and Romans, vol. 2. Rome in the period of the Empire, 367 p. Napoleon V, Auschwitz (2018)
5. Cadiou, F.: L'Armée imaginaire. Les soldats prolétaires dans les légions romaines au dernier siècle de la République. Mondes anciens, 5, 488 p. Les Belles Lettres, Paris (2018)
6. Erdkamp, P.: Army and Society. A Companion to the Roman Republic. N. Rosenstein, R. Morstein-Marx (eds.), pp. 278–296. Blackwell, Oxford (2006)
7. Erdkamp, P.: The Transformation of the Roman Army in the Second Century B. C. War and Territory in the Roman World/Guerra y territorio en el mundo romano (British Archaeological Reports International Series 1530). Edited by Toni Ñaco & Isaías Arrayás; with a prologue by Paul Erdkamp, pp. 41–51. BAR Publishing, Oxford (2006)
8. Morstein-Marx, R., Rosenstein, N.: The Transformation of the Republic. A Companion to the Roman Republic. N. Rosenstein, R. Morstein-Marx (eds.), pp. 625–637. Blackwell, Oxford (2006)
9. Brunt, P.A.: Italian Manpower 225 B.C.-A.D. 14, XXI+762 p. Oxford University Press, Oxford (2001)
10. Cagniart, P.: The Late Republican Army (146-30 BC). A Companion to the Roman Army. Erdkamp, P. (ed.), pp. 80–95. Blackwell Publishing Ltd., Malden, Oxford, Carlton (2007)
11. De Ligt, L.: Roman Manpower and Recruitment During the Middle Republic. A Companion to the Roman Army. Erdkamp, P. (ed.), pp. 114–131. Blackwell Publishing Ltd., Malden, Oxford, Carlton (2007)
12. Gabba, E.: Republican Rome, the Army and the Allies, p. 272. University of California Press, Berkeley, Los Angeles (1976)
13. De Ligt, L.: Peasants, Citizens and Soldiers: Studies in the Demographic History of Roman Italy 225 BC-AD 100, p. 408. Cambridge University Press, Cambridge (2015)
14. De Blois, L.: Army and General in the Late Roman Republic. A Companion to the Roman Army. P. Erdkamp (ed.), pp. 164–179. Blackwell Publishing Ltd., Malden, Oxford, Carlton (2007)
15. De Blois, L.: Army and and Society in the Late Roman Republic: Professionalism and the Role of the Military Middle Cadre. Kaiser, Heer und Gesellschaft in der Römischen Kaiserzeit: Gedenkschrift für Eric Birley. Edd., pp. 11–31. Géza Alföldy Stuttgart Franz Steiner Verlag (2000)
16. Miller, M.C.J.: The Professionalization of the Roman Army in the Second Century B.C. (1984). Dissertations. 2253. https://ecommons.luc.edu/luc_diss/2253
17. Faszcza, M.N.: Rebellions in the late Republican Roman armies (88-30 B.C.). Doctoral dissertation written under the supervision of Professor Adam Ziółkowski, 270 p. University of Warsaw, Warsaw (2014)
18. Harmand, J.: L'armée et le soldat à Rome: de 107 à 50 avant notre ère, p. 539. A. et J. Picard et Cie, Paris (1967)
19. Rankov, B.: Military Forces. Cambridge History of the Greek and Roman Wars, vol. II: Rome from the Late Republic to the Late Empire. Red. P. Sabin, G. van Wies, M. Whitby, pp. 30–75. Cambridge University Press, Cambridge (2007)
20. Adams, C.: War and Society. The Cambridge History of Greek and Roman Warfare. Volume II: Rome from the Late Republic to the Late Empire. Red. P. Sabin, H. van Wees, M. Whitby, pp. 198–232. Cambridge University Press, Cambridge (2007)
21. Southern, P.: The Roman Army: A Social and Institutional History, Cambridge 2007, 383 s. Oxford University Press (2007)

22. Jones, A.H.M.: The decline and fall of the Roman Empire. History **40**(140), 209–226 (1955). JSTOR. http://www.jstor.org/stable/24403110. Accessed 18 Jan 2024
23. Goldsworthy, A.: The Complete Roman Army, p. 224. Thames & Hudson, London (2007)
24. Recruiting, M.S.: Social and Geographical Aspects: The Republic. Encyclopedia of the Roman Army. Le Bohec Y. Malden (ed.), vol. 3, pp. 811–813. Wiley-Blackwell (2015)
25. Cowan, R.: Roman Legionary 109–58 BC: The Age of Marius, Sulla and Pompey the Great, p. 64. Osprey Publishing, Oxford (2017)
26. Rich, J.W.: The Supposed Roman Manpower Shortage of the Later Second Century B.C. Historia: Zeitschrift für Alte Geschichte, vol. 32, no. 3, pp. 287–331 (1983)
27. Sage, M.: The Army of the Roman Republic: From the Imperial Period to the Army of Julius Caesar, 332 p. Pen & Sword Military, Barnsley (2018)
28. Mleke, M.N., Dida, M.A.: A survey of monitoring and evaluation systems for government projects in Tanzania: a case of health projects. Int. J. Inf. Eng. Electron. Bus. (IJIEEB) **12**(1), 8–18 (2020). https://doi.org/10.5815/ijieeb.2020.01.02
29. AlSukhayri, A.M., Aslam, M.A., Arafat, S., Aljohani, N.R.: Leveraging the saudi linked open government data: a framework and potential benefits. Int. J. Mod. Educ. Comput. Sci. (IJMECS) **11**(7), 14–22 (2019). https://doi.org/10.5815/ijmecs.2019.07.02
30. Keawney, A.: The Army in the Roman Revolution, p. 160p. Routletge, New York (2007)
31. Al-khatib, B., Ali, A.A.: Linked data: a framework for publishing five-star open government data. Int. J. Inf. Technol. Comput. Sci. (IJITCS) 13(6), 1–15 (2021). https://doi.org/10.5815/ijitcs.2021.06.01
32. Siddiqui, U.A., Mehmood, W: E-government in Pakistan—implementation and challenges. Int. J. Educ. Manag. Eng. (IJEME) **11**(6), 10–19 (2021).https://doi.org/10.5815/ijeme.2021.06.02
33. Iskandarli, G.Y.: Applying clustering and topic modeling to automatic analysis of citizens' comments in E-government. Int. J. Inf. Technol. Comput. Sci. (IJITCS) **12**(6), 1–10 (2020). https://doi.org/10.5815/ijitcs.2020.06.01
34. McCall, J.: The Cavalry of the Roman Republic, p. 208p. Routledge, London (2002)
35. Taylor, M.J.: Tactical Reform in the Late Roman Republic: A View from Italy. Historia, vol. 68, no. 1, pp. 76–94 (2019)
36. Crawford, M.: The Roman Republic, 270 s. Prószyński i S-ka, Warsaw (1992)
37. Bringmann, K.: A History of the Roman Republic. From the Beginnings to the Time of Augustus, 332 p. Wydawnictwo Poznańskie, Poznań (2010)
38. Ziółkowski, A.: History of Rome. Wydawnictwo Poznańskie, Poznan, 635 p. (2008)
39. Wolff, C.: Les volontaires dans l'armée romaine jusqu'à Marius. Latomus **69**, 18–28 (2010)
40. Labitzke, M.: Marius: der verleumdete Retter Roms, p. 539. Lit Verlag, Münster (2013)
41. Vacanti, C.: Recensioni per: François Cadiou, L'Armée imaginaire. Soldiers serving in the Roman legions in the last century of the Republic. Nuova Antologia Militare. Rivista interdisciplinare della Sosieta Italiana di Storia Militare Storia militare antica, no. 1. Fascicolo 2. Storia Militare Antica, pp. 297–305 (2020)
42. Humphrey, J.W.: An Historical Commentary on Cassius Dio's Roman History, Book 59 (Gaius Caligula) (T). University of British Columbia (1976). https://open.library.ubc.ca/collections/ubctheses/831/items/1.0093872
43. Santangelo, F.: Marius, XII + 124 p. Bloomsbury Academic, London, New York (2016).
44. Koval, A.P.: Military-political and social activity of Pompey the Great. Diss. ... candidate of historical sciences: 07.00.02. Kyiv, 271 p. (2017)
45. Cappi, L.: The Formation of the Roman Army from Republic to Empire. From Republic to Empire, 272 p. University of Oklahoma Press, London (1998)
46. Pilkevich, A.: Transformation of the model of socio-economic structure of the armed forces of Rome (late II century BC-117 AD). Diss. ... candidate of historical sciences: 07.00.02. Kyiv, 17 c. (2010)
47. Harada-Poulter, J.: The Marian Military Reforms and their impact on the Ancient Roman Empire. CORVUS. J. Carlet. Univ. Class. Soc. **10**, 2–14 (2020)
48. Pilkevich, A.: Destructive processes in the system of military organization of Rome and the formation of early elements of army professionalization in the second century BC. Ethn. Hist. Peoples Eur. **45**, 17–20 (2015)

49. Pilkevich, A.: Reforms of Gaius Marius in the system of political and socio-economic transformations in the Late Roman Republic. Bulletin of Taras Shevchenko National University of Kyiv. History, no. 1(132), pp. 43–45 (2017)
50. Cui, S.: The Marian military reform and its effects on the Roman Republic. In: 2021 International Conference on Public Relations and Social Sciences (ICPRSS 2021), pp. 992–998. Atlantis Press (2021)
51. Khoma, I., Fedushko, S., Kunch, Z.: Media manipulations in the coverage of events of the Ukrainian revolution of dignity: historical, linguistic, and psychological approaches. In: CEUR Workshop Proceedings. Volume 2616: Proceedings of the 2nd International Workshop on Control, Optimisation and Analytical Processing of Social Networks (COAPSN-2020), Lviv, Ukraine, May 21, 2020, pp. 25–38. http://ceur-ws.org/Vol-2616/paper3.pdf
52. Oliynyk, M.: Gaius Marius' contribution to the professionalization of the Roman army. Problems of Humanities: Collection of scientific works of Drohobych Ivan Franko State Pedagogical University. Series "History", no. 38, pp. 191–218 (2016)
53. Faszcza, M.N.: Roman Cavalry in the Period of the Decline of the Republic. Nowy Filomata. XIV. Nr. 1, pp. 27–33 (2010)
54. Faszcza, M.N.: Citizen-Soldier in the Roman Republic. The Problem of loyalty to the State Versus Loyalty to the Leader. War, Conflict and Society in the Ancient World. B. Koloczek, E. Osowska (eds.), pp. 160–172. Wydawnictwo Kasper, Krakow (2014)
55. Faszcza, M.N.: "Marius' reforms" and their real authors. Nowy Filomata **1**, 77–86 (2012)
56. Faszcza, M.N.: The process of professionalization of the Roman army in the 3rd-I century BC. In: Belicki, K. (ed.) Roma, Romae, Romae...: Materials from the 1st Inter-University Conference of Student Scientific Circles Centered on Ancient Rome, Warsaw, May 12, 2010 and the 2nd Inter-University Conference of Student Scientific Circles Centered on Ancient Rome, Warsaw, May 20, 2011, vol. 1 and 2, pp. 167–183. AT Group Publishing House, Kraków (2011)
57. Oliynyk, M.A., Strelbytska, S.M.: Changes in the tactics and organization of the legion at the turn of the II-I centuries BC. Zaporizhzhia Hist. Rev. **4**(56), 261–274 (2021)
58. Fedushko, S., Kolos, S., Malynovska, Y.: MBTI principles in detecting emotional manipulators among digital platforms users. In: Proceedings of the International Workshop on Conflict Management in Global Information Networks (CMiGIN 2019), Lviv, Ukraine, November 29, 2019. CEUR-WS.org, vol. 2588. pp. 346–359 (2020). http://ceur-ws.org/Vol-2588/paper29.pdf
59. Graczkowski, A.: On Marius' Military Reform. The Birth and Development of the Professional Army in Ancient Rome (2nd-I century BC), 559 p. Infort Editions, Zabrze-Tarnowskie Góry (2019)
60. Gauthier, F.: Financing War in the Roman Republic 201 BCE-14 CE. A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements of the degree of Doctor of Philosophy. Department of History and Classical Studies. McGill University, Montréal, 263 p. (2015)
61. Rosenstein, N.: Rome at War: Farms, Families, and Death in the Middle Republic, p. 339. University of North Carolina Press, Hapel Hill, London (2004)
62. Suder, W.: Census populi. Demografia starożytnego Rzymu, 299 s. Wydawnictwo Uniwersytetu Wrocławskiego, Wrocław (2003)
63. Faszcza, M.N.: On the reform that was not (Andzej Graczkowski. On Marius' military reform. The birth and development of the professional army in ancient Rome (2nd-Ith century B.C.). Studia Antiquitatis et Medii Aevi Incohantis (SAMAI V 2020), pp. 196–208 (2020)
64. Zhekov, J.: The Reform of Gaius Marius—Myths and Reality. Bulgaria, the Bulgarians and Europe—Myth, History, Modernity: Scientific Conference (Veliko Tarnovo, October 31, 2018), pp. 9–26 (2019)
65. Matthew, K.: The *capite censi* set of Gaius Marius: A Reassessment. Ancient History: Resources for Teachers, vol. 36(1), pp. 1–17 (2006)
66. Matthew, C.A.: On the Wings of Eagles: The Reforms of Gaius Marius and the Creation of Rome's First Professional Soldiers, vol. XVII, 102 p. Cambridge Scholars Publishing, Cambridge (2010)

67. Matthew, K.: The Battle of Vercelli and the Change of the Heavy Spear (Pilum) by Gaius Marius in 101 B.C, vol. 44, pp. 50–67. Journal of Antiquities, Antichthon (2010)
68. Matthew, C.A.: Mules Maria. Rome's New Infantry. Ancient War: The "New Men" Who Saved Rome, vol. V(1), pp. 13–18 (2011)
69. Gauthier, F.: The changing composition of the Roman army in the late republic and the so-called "Marian-Reforms." Anc. Hist. Bull. **3–4**, 103–120 (2016)
70. Repaso de, G.S.R.: François Cadiou. L'Armée imaginaire. Les soldats prolétaires dans les légions romaines au dernier siècle de la République. Nailos. Estudios Interdisciplinares de Arqueología. Oviedo, pp. 250–253 (2018)
71. Petitjean, M., Cadiou, F.: L'Armée imaginaire. Les soldats prolétaires dans les légions romaines au dernier siècle de la République. Mondes anciens, 5, 488 p. Les Belles Lettres, Paris, 2018. Revue internationale d'histoire militaire ancienne, no. 7, pp. 186–188 (2018)
72. Rafferty, D.: Review of the book: Cadiou F., L'Armée imaginaire. Les soldats prolétaires dans les légions romaines au dernier siècle de la République. Mondes anciens, 5. 488 p. Les Belles Lettres, Paris (2018). Bryn Mawr Classic Review. https://bmcr.brynmawr.edu/2021/2021.06.02/. Accessed 02 Jun 2021
73. Cadiou, F.: Le dilectus de l'année 151 et les guerres celtibéro-lusitaniennes: remarques sur la question de la réticence face au service militaire dans la Rome du IIe s. av. J.-C. Transforming Historical Landscapes in the Ancient Empires. Proceedings of the First Workshop of the Area of Research in Studies from Antiquity. Edd. B. Antela-Bernárdez and T. Ñaco del Hoyo, Barcelona, December 16–19th 2007, Oxford (BAR, International Series 1986), pp. 23–32 (2009)
74. Blois de, L.: Army and general in the late Roman Republic. In: Erdkamp, P. (ed.) A Companion to the Roman Army, pp. 164–179. Blackwell Publishing Ltd., Malden, Oxford, Carlton (2007)
75. Syllac, S.: L'armée imaginaire. Et si on repensait l'histoire? Nouvelles publications. L'université Bordeaux Montaigne. https://www.u-bordeaux-montaigne.fr/fr/actualites/nouvelles-publications/l-armee-imaginaire-et-si-on-repensait-l-histoire.html

"Deprivation of Control" and an Evolution of the Institution of Expatriates: A Case Study of Changing HQ Controls Over Subsidiaries in a Norwegian MNC Internationalization Process

Irina Roddvik, Solomiia Fedushko, and Anatoli Bourmistrov

Abstract This paper explores the evolution of management control systems in a multinational corporation (MNC) during different phases of internationalization. Focusing on top managers' perceptions at the headquarters (HQ), the study investigates how a "deprivation of control" drives changes in expatriate control mechanisms. Departing from traditional perspectives, the role of the research highlights the individual agency in shaping institutional change. Using a Norwegian MNC as a case study, the paper traces the company's internationalization journey and reveals significant transformations in expatriate control mechanisms. A key finding is the emergence of "deprivation of control," a shared mental state among top managers that influences the strategic tuning of expatriate roles to address specific challenges during internationalization. The study contributes by integrating psychological research to understand changes in management control. It emphasizes the dynamic evolution of expatriate roles, challenging the notion of achieving total control and influence over subsidiaries. The findings suggest a nuanced approach to designing control tools during internationalization.

I. Roddvik
Østfold University College, Halden, Norway

Oslo Business School, Oslo Metropolitan University, Oslo, Norway

I. Roddvik
e-mail: irina.n.roddvik@hiof.no

S. Fedushko (✉)
Lviv Polytechnic National University, Lviv, Ukraine
e-mail: solomiia.s.fedushko@lpnu.ua

Comenius University Bratislava, Bratislava, Slovakia

A. Bourmistrov
Nord University Business School/High North Center, Bodø, Norway
e-mail: anatoli.bourmistrov@nord.no

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2024

P. Štarchoň et al. (eds.), *Data-Centric Business and Applications*, Lecture Notes on Data Engineering and Communications Technologies 213,
https://doi.org/10.1007/978-3-031-62213-7_5

Keywords Management control systems · Control system evolution · Internationalization process · Multinational corporation · Internationalization · Expatriate controls

1 Introduction

This paper seeks to contribute to management accounting and control change literature by examining how the evolution of a control system is a result of top managers' perceptions of the outcome of control activities [1]. The paper does so by examining how the top managers in the HQ of an MNC [2] during different phases of its internationalization process have tuned the control mechanism of expatriates driven by a 'deprivation of control', that is, a mental state of wandering and striving to achieve a high level of influence over its international subsidiaries.

Changes in management control systems have been studied over the years from various theoretical perspectives, e.g., mostly from contingency or institutional (e.g., [3]) perspectives. These studies have improved our understanding of how internal and external contingency factors and different institutional pressures produce changes in management control systems and why and what consequences for organizations. Recently, there has been increasing attention towards extending this literature by examining the role of individual agencies in producing institutional change in management control systems, for example, the role of institutional work and institutional entrepreneurs [4].

Considering this trend of moving from the role of social towards exploring the role of the individuals in accounting and control research, it is appropriate, thus, to better understand management accounting and control system change, it is important to consider the opportunities provided by psychological research [5, 6]. Understanding how managers perceive controls is crucial because it impacts their judgment and beliefs about the control system's effect on organizational behavior and outcomes. Previous studies have explored how managerial perceptions of controls impact control system design changes [7–9] (Koeing et al. 1992). The effects of perceptions on the design and use of management control systems are thus essential to study further.

This paper studies the evolution of controls in international settings. Our study concentrates on the perceptions of top managers based at the headquarters of a multinational corporation (MNC) regarding the control process. We aim to understand how they have perceived the degree of influence the HQ has over international subsidiaries during different stages of the internationalization process. Additionally, we want to examine how these perceptions have influenced the design of the HQ's control mechanism over its subsidiaries. The process of internationalization is a fascinating research area because of the increasing impact of globalization on businesses. As companies expand internationally, they need to establish effective control mechanisms that allow them to exert significant influence over their subsidiaries. This is particularly challenging as these subsidiaries often operate under different

regulatory and cultural environments than the company's headquarters [1, 10]. One effective way for HQ to exert influence over subsidiaries in international settings is through the Institute of Expatriates. The role of expatriates in MNCs has been in the research domain for several decades [11, 12]. Numerous studies have focused on how headquarters (HQ) use expatriates to manage their subsidiaries [12, 13]. However, these studies have not explored how managerial perceptions of control outcomes impact the changes made to the expatriates' controls. By making a retrospective review of the internationalization of a Norwegian multinational company 'T', step by step, this paper demonstrates a dynamic interrelation between the internationalization behavior of an MNC, the evolution of its expatriate controls, and the internationalization process's impact of the HQ's influence on its subsidiaries abroad as perceived by top managers.

Our empirical story shows that MNC 'T', as a company, has faced dramatic changes during the last decades after the internationalization process started in 1993 that required the establishment but also substantial revisions over time, of the institution of expatriates as a control mechanism of influence and HQ control over its subsidiaries abroad. The empirical shreds of evidence show that at the beginning of internationalization, the expatriates were "passionate ambassadors"—people who established their first contacts abroad, provided knowledge to HQ, influenced top management, and participated in essential networking arenas on the markets. During the first phase of investments abroad, when "T" established its activities in several Joint Ventures (JVs), expatriates became individual consultants to support local top managers in solving management problems. During the next stage of internationalization, when the 'T' consolidated its activities abroad, expatriates turned to become top managers in subsidiaries that could bring the necessary professional expertise from the HQ and establish a team of high professional teams around them in subsidiaries. In the mature phase of internationalization, expatriates are considered to be highly skilled and influential managers who are responsible for establishing a company's values, culture, and governance in its subsidiaries. They are expected to be the carriers of the headquarters' DNA and implement the company's way of doing business. "T" started to recruit expatriates for managerial positions at subsidiaries abroad and outside of "T." We discover that this evolution of the expat control system, from "individual consultants" towards "a DNA" pool, was driven by a particular perception of the top managers that we call "deprivation of control'. 'Deprivation of control' is a shared mental state of the top managers of MNC T in different periods of internationalization that signifies their continuous inability to secure appropriate control outcomes to achieve a high level of influence over the subsidiaries. This perception of "discomfort" [14, 15] was developed over time because of the incongruence between the internationalization process and its ascendancies, the use of the expat-control as a control mechanism, and the outcome of the control process. In the context of international business, the term "deprivation of control" refers to the feeling of discomfort experienced by a manager when they are unable to establish effective control mechanisms over their subsidiaries, which results in a lack of desired influence. This feeling arises due to the manager's inability to design adequate control mechanisms. Tuning the role of expatriates during the internationalization process

aims to mitigate experienced "deprivation of control" among top management. In the next section, we review previous research on the role of expatriates in MNCs during the internationalization process, as well as the role of perceptions in designing and changing management control systems. After that, we present the research methodology followed by a case analysis of the evolution of the role of expatriates in the internationalization process of the Norwegian MNC "T" as one of the mechanisms to achieve influence from HQ towards subsidiaries.

2 Related Work

The research papers on the subject of deprivation of control and management control systems in a multinational corporation in the Scopus scientometric database were analyzed. 403,280 documents were found using the search query TITLE-ABS-KEY (management AND control AND systems) in the Scopus scientometric database from 1920 to 2023. According to Fig. 1, the importance of the research topic among scientists is growing, with a strong growth in the publication of scientific documents starting in 2004.

We also conducted a research search in Scopus, narrowing down the subject matter, using the search query—TITLE-ABS-KEY (management AND control AND systems AND multinational AND corporation) AND (LIMIT-TO (SUBJAREA, "SOCI") OR LIMIT-TO (SUBJAREA, "BUSI") OR LIMIT-TO (SUBJAREA, "DECI") OR LIMIT-TO (SUBJAREA, "ECON") OR LIMIT-TO (SUBJAREA, "PSYC") OR LIMIT-TO (SUBJAREA, "ARTS"))). The result of this query is 119

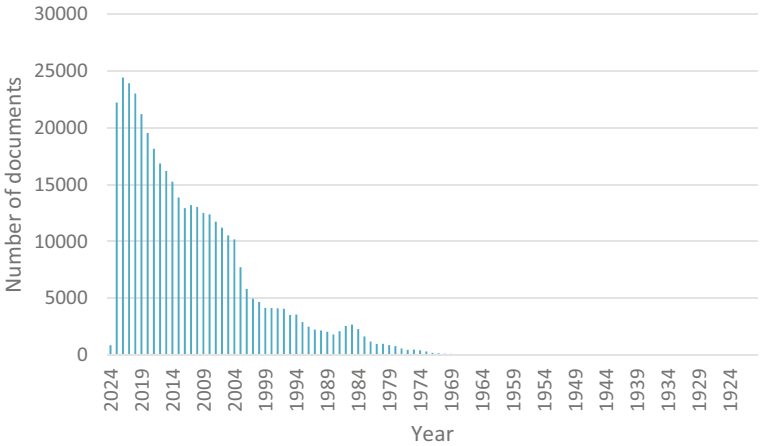


Fig. 1 Статистика за пошуковим запитом TITLE-ABS-KEY (management and control and systems) у Scopus

documents published in reputable scientific journals. We used the software instrument to analyze these data to create maps based on network data and visualize and explore maps VOSviewer [16, 17]. The results are summarized and visualized using VOSviewer by creating maps based on network data: network visualization (Fig. 2), overlay visualization (Fig. 3), density visualization (Fig. 4). The graphs of the network visualization (Fig. 2), overlay visualization (Fig. 3), and density visualization (Fig. 4) of the documents included the results of the investigation in the fields of management control in the multinational corporation. The data includes 53 research documents, classified into 2 clusters from a total of 6629 items.

Table 1 presents an overview of the analysis of the literary works in the deprivation of control within a multinational corporation based on the analysis of the maps based on network data. The table is organized by different research fields, providing a snapshot of each category's key themes and topics.

Utilizing the VOSviewer software, we visually represented and explored the network data through network visualization (Fig. 2), overlay visualization (Fig. 3),

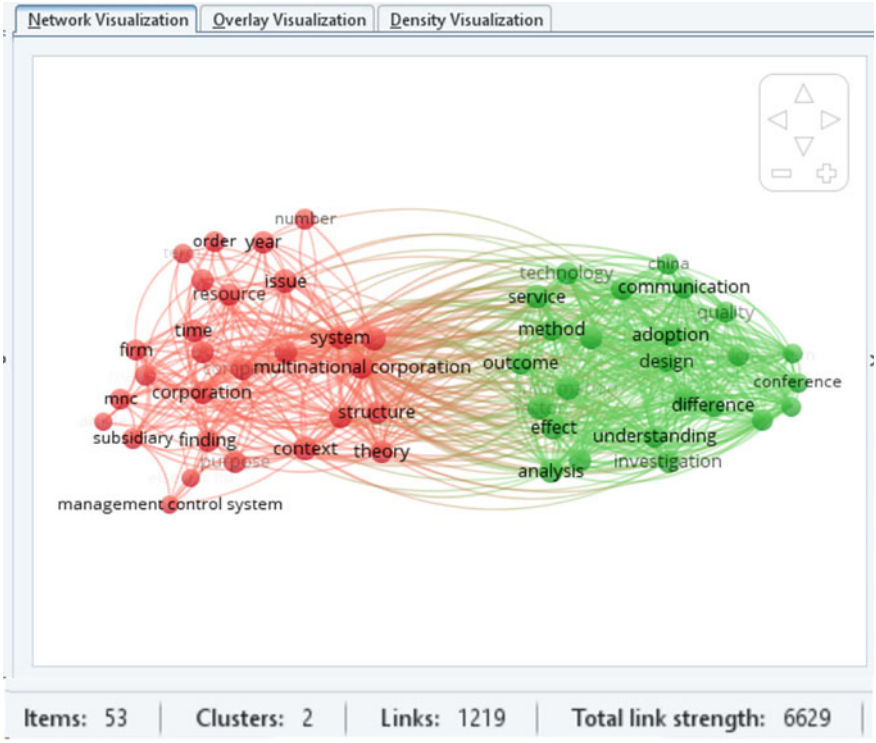


Fig. 2 Network visualization

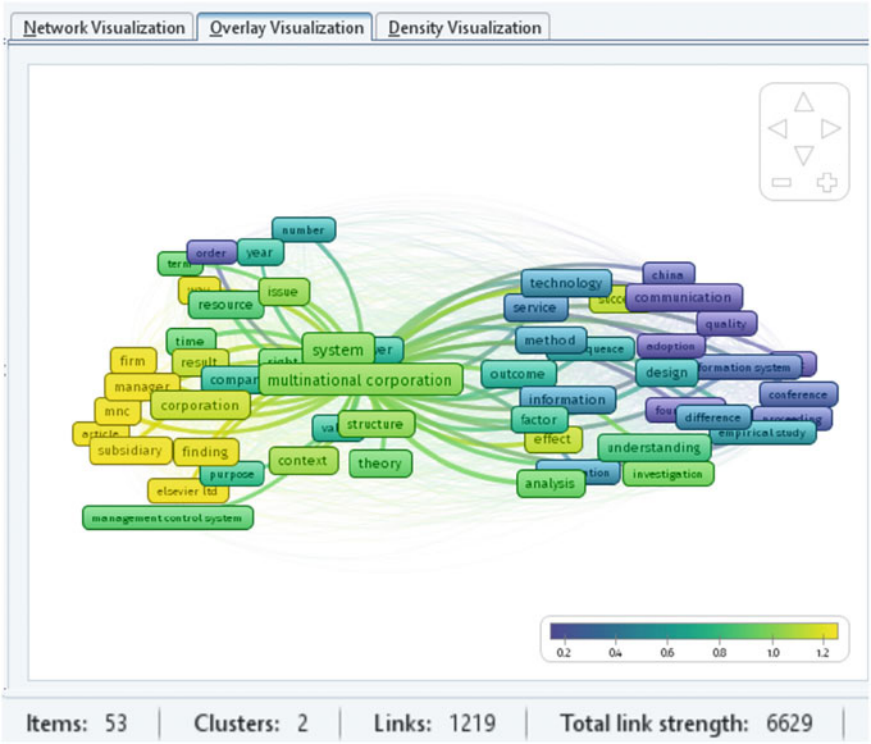


Fig. 3 Overlay visualization

and density visualization (Fig. 4). The data was further distilled, and 53 research documents were classified into two clusters out of a total of 6629 items. These visualizations offer valuable insights into the interconnectedness and thematic concentrations within the literature.

The analysis of research papers on the deprivation of control and management control systems in multinational corporations reveals a significant and growing interest among scholars. The search in the Scopus scientometric database yielded a substantial number of documents, with a noticeable surge in publications since 2004, as depicted in Fig. 1. To delve deeper into the specific context of multinational corporations, a refined search resulted in 119 documents from reputable scientific journals.

Table 1 summarizes the analysis findings, presenting a categorized overview of research fields related to the deprivation of control in multinational corporations, reflecting the multifaceted nature of the research landscape. This comprehensive analysis contributes to understanding the evolving landscape of research in the field and provides a foundation for future exploration and inquiry into the nuanced dynamics of control mechanisms within multinational corporations. As scholars continue to delve into these intricate dimensions, the body of knowledge is expected to expand

Fig. 4 Cluster density visualization

further, offering deeper insights and practical implications for management practices in a global context.

3 Theoretical Framework

Influence and control by HQ over subsidiaries via expatriates

The research literature has reported increased interest in the role of expatriates because of the increasing challenges connected to internationalization in MNCs. Expatriates are managers deputed from the multinational headquarters to the firm's overseas JVs [12]. Expatriates are expected to manage the JV through its liabilities of newness and foreignness to provide stability to the new organization through effective deployment of multinational enterprise's (MNE) capability and expertise and ensure that the JV achieves the required level of performance.

Table 1 The results of review analysis of the papers from the fields of deprivation of control in a multinational corporation

Research field	Analysis of the documents
Management control systems in multinational organizations	– Time–space odyssey, multinational organizations [18] – Control and coordination in global ERP configuration [19] – Employee commitment in MNCs, organizational culture [20]
Wholly-owned foreign subsidiary control	– Transaction cost economics theory, foreign subsidiaries [21] – Host country resource availability, information system control [22]
Social impact of corporations and supply chain management	– Management control interventions, worker wages [23] – Transformative potential of management control systems and sustainability [24]
Levers of control framework in a manufacturing setting	– Competitive forces, multinational subsidiary [25] – Institutions, agency, culture, and control [26] – Performance measurement in multinational corporations [27]
Practice sharing and forecasting, conflictual practice, and organizational culture	– Conflictual practice sharing, organizational culture [28] – Resisting a corporate code of ethics management control [29] – Multiplicity of performance management systems in multinational corporations [30] – Forecasting Economic Parameters [31, 32] – Top managers' formal and informal control practices [33] – Product innovation processes [34, 35]

One research stream investigates expatriates' individual professional qualities to achieve influence. The role of expatriates can also be considered in terms of transferring knowledge from parent company/HQ to subsidiaries [12]. There are two types of knowledge that a parent company can have: marketing knowledge and technological knowledge. It is generally expected that multinational corporations (MNCs) with a high level of marketing or technical capabilities will use expatriates to transfer this knowledge to their foreign subsidiaries. There are two types of expatriates in MNCs: "in-group" expatriates, who are trusted by HQ and possess core corporate knowledge, and "out-group" expatriates, who lack such knowledge and require training. Ethnocentric staffing policies often result in expatriates receiving higher salaries and benefits compared to host-country nationals. This can lead to locals feeling dissatisfied with the level and quality of work they contribute in comparison to their compensation. According to a study by Yan and Gray in 2004, the ownership of equity by partners impacted the selection of expatriate employees for a joint venture.

However, other control mechanisms like partner knowledge dependence and specific asset investments did not have a significant effect. Majority equity ownership, which confers bargaining dominance, did not seem to be a major factor in explaining joint venture control mechanism.

Another research stream investigates expatriates' role in influencing operational control [36], local practices, and subsidiary performance [37]. For instance, in subsidiaries with 100% ownership—the wholly owned subsidiary (WOS)—expatriates are strongly involved in decision-making processes and providing the HQ strategy in subsidiaries. Expatriates provide formal feedback and report to HQ. Thus, the high level of operational control and influence from HQ follows the strong role of expatriates in subsidiaries and their practice in replicating the control mechanisms from HQ towards subsidiaries (Charlos and O'Conner 2004). As key managers, expatriates can influence organizations abroad on the behavioral, cultural, and social levels of communication. Dutta and Beamish [38] highlighted that the management teams of multinational corporations, along with the culturally influenced decision-making of managers and expatriates, play significant roles in shaping organizational outcomes. This understanding can increase their influence on the organization.

To summarize, existing research indicates how expatriates can impact the performance of subsidiaries in WOS and JVs by increasing revenue and decreasing costs [38]. Expatriates play a crucial role in transferring organizational knowledge, including tacit knowledge, and assimilating practices from HQ to subsidiaries. The research literature, however, does not seem to pay much attention to how the role of expatriates, as a control mechanism used by HQ to get influence over subsidiaries, may change during the internationalization process and in what factors can affect this change in the role.

3.1 Perceptions of Controls and Effects on Changes in the Management Control Systems

Previous studies have shown how changes in the management control system may be related to changes in decision-maker's perceptions [39], though many of those only implicitly [40–52]. Hall [5] suggests that there should be greater use of psychology theory in management accounting and management control research. One approach is to explore how managerial perceptions of controls influence their judgment and beliefs about the impact of the control system on organizational behavior and outcomes. For example, [7] examined how managers who experienced a state of mental "discomfort" with the control outcomes introduced changes in the control system configuration to enable new behavior and a new state of mental "stretch." The literature on organizational sociology and psychology uses the concepts of "comfort" and "discomfort" zones to describe individual perceptions. The interpretation depends upon a correspondence or lack of correspondence between the decision-maker's mindset and actual behavior at work. The term "mindset" usually refers to

an individual's attitudes and assumptions about how the world works, including their work identity. "Behavior" refers to the actions that are taken or should be taken in a specific work situation. Managers tend to positively appraise work situations that are characterized by an anxiety-neutral mindset, where there is a match between behavior and mindset. This is known as the "comfort" zone. In contrast, the "discomfort" zone is a state where there is a higher level of anxiety due to a misalignment between established mindset and behavior. Managers' perception of discomfort can lead to a substantial redesign of the management control system, as shown by [7].

Managers may hinder changes by overestimating the control system's impact on organizational outcomes, according to research. The phenomenon where managers fail to realize that traditional controls used by an organization do not actually control behavior is called the "illusion of control" [8, 9]. This means that the actual behavior and control outcomes are influenced by other processes in the organization rather than just traditional controls.

The concept of "illusion of control" is discussed in psychology literature. People tend to take credit for their successes but attribute their failures to external factors. Managers' perceptions can influence their judgment of cause-outcome relationships when the potential cause is an uncontrollable external event. Based on the literature that relates perceptions of controls and changes in the control systems, we are interested in exploring how, during the internationalization process, the control relationships (and the outcome of these relationships) between HQs and subsidiaries were perceived by managers in HQs and whether/how such perceptions have subsequently influenced changes in the HQ control system over subsidiaries.

3.2 A Theoretical Model

Figure 5 summarizes the theoretical model for the study. We assume that the internationalization process affects the organization and managers regarding issues around HQ's control over subsidiaries and HQ's influence over subsidiaries as an outcome of control activity. We examine the particular role of expat-controls. For individual managers, the effects of expat-controls are studied in terms of the perceived influence of HQ over subsidiaries. Then, we study how managerial perceptions, in turn, relate to attempts of top managers to redesign/change expat-control by HQs in terms of setting a different configuration of the institute of expatriates. In turn, the changes in expat expat control can facilitate changes in internationalization. We have formulated two research questions:

- How has the configuration of expat controls changed during the different phases of an MNC internationalization process?
- How can those changes in the configuration of expat-controls be attributed to changes in the top managerial perceptions of the output of expat-control in terms of HQ achieving influence over subsidiaries?

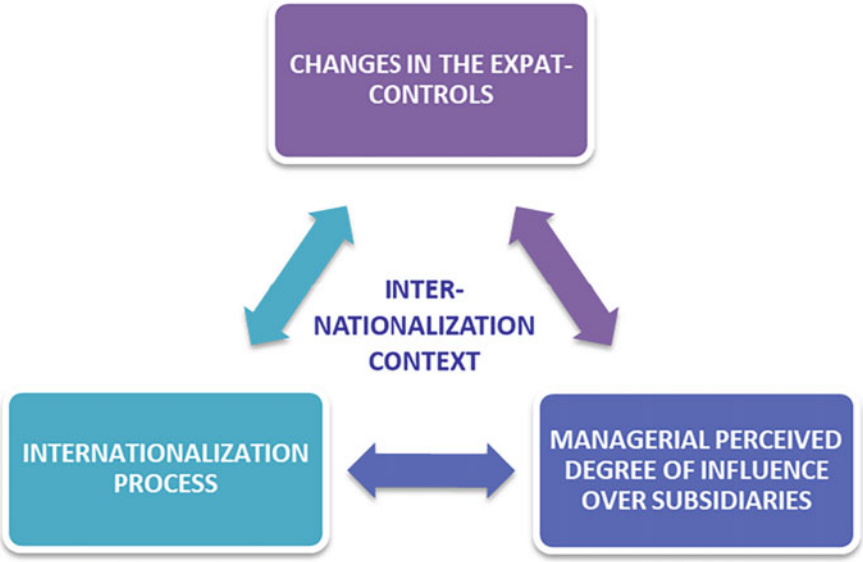


Fig. 5 The research model

3.3 Research Setting and Methods

This is a case study of a Norwegian MNC, "T" both HQ and some of its subsidiaries abroad. The primary source of empirical data was interviews, 37 face-to-face interviews, and conversations being held with "T's employees. The topic related to the role of expatriates is connected to almost all respondents, who had strong reflections and opinions. Many of the respondents have been expatriates themselves. Many of the respondents cooperated and are still cooperating with the expatriates. Both structured and unstructured interviews were the primary and most effective method of data collection. They allowed me to delve deeper into the research problem through in-depth, face-to-face interviews with informants and the focus groups they belonged to. Most of them were tape-recorded and later transcribed, contributing to collecting unimpaired notes but with all information available later for complete analysis. Since the interviews were exploratory in nature, special attention was paid not to steer the conversation toward the author's personal viewpoints.

Questions that were asked aimed to explain the practices in HQ and subsidiaries while attempting to understand their cultural value comparison of employees in subsidiaries and reasons behind different practices. Two languages were used for data collection (English and Norwegian).

There are two former CEOs, former executive board members and board members, as well as current executives at "T" who will conduct the interviews. Access to exclusive groups is highly restricted due to the sensitivity of the information collected [53]. In this connection the majority of data was collected them in a period from

2011 to 2017, and the topics of many interviews were linked to the historical aspects describing the process of internationalization from 1991.

One of the authors of this paper is also an employee of "T". Thus, they had direct access to internal company documents, reports, and "T's" employees. However, the researchers only used information that could be published based on their agreements with "T". This access made it possible for the authors to communicate informally with T's employees, allowing them to complement the information provided by face–to–face interviews. Informal meetings were helpful in clarifying key issues and discussing relevant topics related to the research questions. In addition, secondary sources, such as annual reports, have been used to support the primary sources and verify the information from interviews. It is important to note the contribution of one of the authors from T to the research process. As an employee of "T" for 19 years, I have had the privilege of accessing information, sources, and informal contacts with other employees. This informal interaction has allowed me to gain valuable insights and knowledge about the company, making me a valuable resource for my colleagues. At the same time, during the long career in "T," the person has actively participated in many processes that are now described and analyzed. As a significant portion of the empirical data has been gathered through personal interviews with the managers and employees involved in the process of "T" and known personally to the author, any issues related to the disclosure of research results will be handled with utmost care. This is directly dependent on the depth of data received from the interviewees. Exploring literature and data related to the described processes were the good sources to understand the reasons for the internationalization process, the development and implementation of different mechanisms of influence, and the role of expatriates, specifically. To structure the empirical evidence, we organized data in historical retrospectives and defined the internationalization process in different periods. We tried to identify the primary triggers of the described process following "the main drive" of action and the flow of events that followed the change in the organization, i.e., change in the role of expatriates.

4 Evolution of the Role of Expatriates in a Norwegian MNC "T"

Based on empirical evidence, the internationalization of "T" is divided into four phases. Different roles of expatriates can also characterize each phase.

Phase 1 in the Internationalization of "T" (1992–1996): "a Small Company and Small International Steps"

The company was first a part of the Norwegian Ministry (SOE) and was 100% owned by the state. The necessity for privatization and internationalization leading to organizational changes in "T" started due to the liberalization of telecommunications marked by the EU, increasing globalization, and, in this connection, the need to start

"T's" international expansion. The international expansion had to be based on the view that "T" should be an international industrial investor due to its 160 years of technical competence in building telecommunication networks in challenging and demanding geographical conditions such as Norway.

Like many other Norwegian companies, T started its internationalization late in the 90s without any experience working in a global multinational business community when cross-cultural tensions can be challenging. "T," in the first period of its internationalization, did not have enough money to invest abroad, and the first international investments were made in 1993. The first investments were also made in Central Europe in Hungary due to an invitation from other Nordic telecommunication operators to be in a consortium. All of "T's" investments abroad during this period were low-cost projects with small shares in JVs. "T" preferred to have a small share of JV's projects because of a lack of international experience. In this period, it was not an issue of what technology is good or wrong for the investments abroad, whether "T" needs control or influence in its JVs, or what mechanisms "T" uses or needs to use targeting to get a footprint on the markets abroad. The logical and natural development of the European market forced the top management of "T" to think about the international projects that had an impact on the development of the whole organization (interview with the former executive board member of "T," 2015). Several processes, primarily political, started in 1992–1993 to change the organizational structure of "T." The ownership model ended with a stock-exchange listing in 2000 on the Oslo Stock Exchange and in NASDAQ (the company was delisted from NASDAQ in 2007).

At the beginning of the 90s, "T" lacked international experience, a global team, a clear expansion strategy, and a project follow-up method. The formal institution of expatriates did not exist, and T had no common corporate rules that could be applied abroad. Therefore, this topic was not an issue during the first international investments.

As was mentioned in several interviews, the internalization in "T" was driven by so-called "*passionate ambassadors*" during this period.

> We needed passionate ambassadors who could represent us and find good partners and projects. (former EVP in legal issues).

> It was mentioned that having "the good ambassadors" in subsidiaries (former EVP in HR) is important.

> "T" people were akin to cowboys in the 1990s. We hailed from a small country with no direct connections to many countries in Eastern Europe and Asia. Despite our lack of financial resources, we possessed a wealth of competence and courage. The tempo was an important element for us. Furthermore, passionate people were the key" (former EVP responsible for the mobile operations).

Those known as "passionate ambassadors" lacked formal positions as expatriates or control functions. Despite facing some challenges, the employees of HQ were trusted and had a close relationship with the top management of "T." They played a

significant role in the process of internationalization by acquiring essential knowledge and establishing crucial connections with potential partners and local authorities abroad. They traveled worldwide and established the contacts needed, got the knowledge about the foreign markets and brought it back to the HQ, influencing the business decisions. When the first investments were made abroad, passionate ambassadors worked in joint ventures or country offices to facilitate transfer of knowledge and contacts.

> After achieving success in international projects, we realized our technological expertise could influence local partners (former Executive Board member responsible for international operations).

> "What initially aided us in the process of internationalization was the fact that our country was small, peaceful, and possessed highly advanced technical skills. We were never perceived as a threat and always remained supportive. Our team was successful in building strong relationships with our international partners and authorities." (This statement was made by a former executive manager who had almost 30 years of experience working in both Norway and internationally in the field of "T".)

> Our passionate ambassadors were skilled individuals who were not afraid to travel. Being Norwegians, they understood the importance of building telecommunications and were always on the lookout for good projects. It was crucial for them to not sit at home but to travel and search for opportunities.

In summary, gaining the efforts of the "*passionate ambassadors*" and forced by the drive of further international expansion, the "T"'s top managers decided to expand internationally. "T" needed more people who could work internationally while being highly qualified professionals.

Phase 2 in the internationalization of "T" (1996–2001): "Planting the flags – the "Viking Strategy""

In this period, "T" experienced increasing international expansion by establishing several JVs abroad. From 1996 to 2000, several small acquisitions were made that built up the framework around international expansions and the foundation for further international strategy development. In the "T"'s annual report from 1999, we can read the following:

> "T" currently holds minority shareholdings in 13 mobile operations abroad, mainly in European countries. The company plans to use this as a foundation to expand internationally in mobile telephony. Their strategy is to become a major provider of mobile services in the Nordic region and to strengthen their position in Eastern and Central Europe as well as Southeast Asia, whether independently or in partnership with other companies.

Several of "T"'s key persons admitted that no clear strategy was backing up this international expansion process. A former member of Group Executive Management described the strategy as the "Viking's way to do things"—"T" people or "passionate ambassadors" traveling around and "planted the flags" in different countries, establishing good relationships with the local partners and authorities, finding the business possibilities.

In this period, "T" invested in several projects in Central and Eastern Europe and Asia that were emerging markets, which gave good results and increased international knowledge and competence among "T" managers working internationally.

> We had to invest in countries where we could find suitable companies to invest in. Looking back, I can say that we made investments with minimal capital and yet, we had the opportunity to earn good profits in the future. Such countries were markets with high risks. We had to manage it even though we did not have sufficient influence. We learned how to deal with it while we worked there: we needed to send qualified consultants to run the operations and learn the local managers. We were enthusiastic cowboys with a state as an owner. Furthermore, there was not conflict in it. In the initial phases of expanding our business globally, we observed the advantages of having state ownership. Even though we did not have sufficient money for the investments, we knew that we had a backup from the state, and if the bad results could come, they would not come out as "red figures" when a company is on a stock exchange. Many partners wanted an investor from a state-owned enterprise as it gave them a sense of safety. (former EVP responsible for the international mobile operations).

Thus, "T" needed to have the expatriates as consultants in the JVs in emerging markets to support the local managers in their professional skills. At the same time, empirical evidence shows that the top management of "T" disagreed about the international strategy. During an interview conducted in 2014 with the former Executive Vice President, who was responsible for all international activities at the corporate level, it was explained that "T" did not have the ambition to own 100% of its subsidiaries abroad. Instead, recognizing its limitations in international experience, it aimed to be a minority member of a strong alliance with a powerful and experienced Western-European operator on the mature markets [1]. The respondent suggested that "T" had a strategy to primarily focus on mature markets as a priority. They believed it was safer to invest in mature European markets than emerging ones. (Ibid.)

> I was in charge of developing the partnership with British Telecom (BT) in the early 1990s. Together, we invested in markets such as Germany and Ireland as joint ventures. Our strategy was to focus on markets where we had expertise, such as Southern or Western Europe, and where we could utilize our technology effectively. (Ibid.)

At the same time, the respondent confirmed from other interviews that T. did not have enough capital to invest in Western or Southern European countries and obtain a significant stake. T. could acquire small shares in mature markets, meaning developing the strategy to be a partner in JVs.

> Nevertheless, it was a good reason for having small stakes and not sharing the risks but building the alliance with the predictable and solid Western partners working in a known environment. We could work via BoD. We had an excellent relationship with the British. We understood each other. It was a good and real cooperation even though we were in the minority position in several JVs. We did not need to send the consultant to work on the permanent base in JVs in Western Europe (Ibid).

A group of top managers was working via BoDs for investments in mature markets with limited influence and limited presence in JVs.

> It is true that we did not have the dominating position in JVs—we were minorities and did not have enough influence and control. Our business partnership was forged on mutual trust and a shared understanding of our respective business models (former EVP responsible for all international activities from the corporate level).

The opponents insisted on the active role in JVs when consultants should support local managers and simultaneously could have a "watch" over the operations.

> If we stayed in the alliance with BT, we would always be just another small partner from a small country without having control and influence, which would follow in the future to the position of being a small partner in different JVs. We did not know what to do in 1992–1993. Everything was new. Maybe it sounds not original to say in 2014 that a low level of ownership follows a low level of influence. Nevertheless, in 1993, when we didn't have a clear strategy, we had no experience. However, we were persuasive in technology. Our strategy involved exploring markets where we could utilize our technological expertise and invest small capital, with significant potential for growth in the future through increasing our shares. Essentially, we were searching for affordable markets with promising prospects. We learned about the local staff and could have our "eyes" on local organizations. (former EVP responsible for International Mobile Operations)

As a result of the internal "tug of war" ended with the decision by the Executive Board and CEO to focus on the emerging markets and to sell the shares in JVs in mature markets, leaving the alliance with BT despite good cooperation and good partnership, concentrating on the investments in the mature markets in Central and eastern Europe and Asia.

Too different respondents commented on this in the following ways:

> It was very pity. We understood each other, had a similar mentality in how to do business, and could understand language and communicate directly with the partners (the former Executive Vice President was responsible for overseeing all international activities from a corporate level.).

> Emerging markets and JVs gave these possibilities, for example, in Hungary. We started there with 5% ownership in the consortium, and increased more and more to 100%" … (former EVP responsible for International Mobile Operations).

Thus, the lack of money, small size of the company, and state ownership (100% of "T" belonged to the state) forced "T" to go for the markets where they could establish "low-cost" JVs and at the same time, have the possibilities to increase its shares in JVs in order to increase business possibilities for the growth. In this connection, "T" could establish just JVs where its influence was limited, and first of all via the board of directors BoD. "T" needed to send the expatriates -consultants to the JVs in emerging markets. Several consultants were employed from HQ to work in JVs to transfer the competence from HQ and support the local management. The role of consultants was anchored in the first Management Agreements. The need for consultants was described in this way:

> We needed good consultants who understand the business and could work in different cultures. we had to recruit them among our employees who we thought were good (former EVP).

"T" needed to train the local staff in subsidiaries and choose to use the consultants and advisors to the top management in the subsidiaries. In this connection, highly qualified professionals were recruited. Many of the employees stationed in the subsidiaries were skilled in areas which the local companies lacked competence in, such as finance, marketing, and technical knowledge. However, their stay was

intended to be short-term as the responsibility of managing the subsidiaries was to be taken over by the local managers.

Those consultants or advisors mainly worked as individuals and were not organized as a team linking to the professional teams in HQ so long the HQ at this time mainly had the "Norwegian focus," and the international department was not significant. T Consultants were not appointed to key positions in subsidiaries because a joint venture with minority ownership prevented "T" from appointing their employees to executive positions with decision-making power. "T"'s employees functioned mainly as personal individual consultants for the top management and, thus, could not influence formal decisions or have any formal control function. The consultants did not have a reporting function to HQ and could only provide informal opinions during on-site visits.

Furthermore, the consultants lacked the authority to influence the conduct of the local personnel responsible for providing or executing the implementation of corporate values. This was because at that time, "T" did not have any shared corporate governance objectives aimed at implementing it in joint ventures (JVs). "T" had the documents that were used only in Norway. They wrote in Norwegian without considering international business issues such as corruption, codes of conduct, and transparency. However, in most cases, the local joint ventures have benefited from using consultants by receiving high-quality support that has led to successful development of local markets and further international expansion of "T."

> I remember how one of the JV CEOs told me that when his company invited foreigners to be co-partners, they looked towards "T." At the end of the 90s, our company was facing a challenging situation. However, we did not regret choosing Norwegians as they had excellent technical skills and managed to align many things. During the first years after "T" became a co-partner in this company, many workshops were arranged to improve the professional skills among managers of the JV. Consultants from "T" were the best specialists who trained their skills on the challenging market in Norway" (personal observations).

However, not all the cases from using the consultants were successful. First, consultants were distant from the local executives and employees. For instance:

> The Norwegian consultants were located on the not "executive"—flour, several flours up than the local CEO in a company. Around the CEO, just his administration was located. Other top managers with whom the CEO used to have contact were located not far from the CEO's office but a short distance from the chief. Norwegian consultants supported to be first-class experts in technical skills and reported to the company's CTO (chief technical officer). They reported to him and worked primarily with the specific technical issues).

> One of the local CEOs from Eastern Europe said that two Norwegian consultants came to his company and misunderstood the issue of the local working traditions. The consultants left their jobs as they are used to in Norway after working 7.5 h. They did not notice that the local employees could leave their workplace either when the tasks were done or when the local manager allowed them to leave. … According to the Management Agreement, the private driver provided consultants. When the restaurant visits were late, it also became an issue so long as the driver could not work as many hours as he had to in addition to that the locals complained that the consultants came late to the working places because of the late restaurant visits. Local employees noticed that the consultants lacked knowledge of cultural traditions, particularly regarding the working relationship. The consultants were accustomed

> to flat organizational structures, which was not the norm for Eastern Europeans. The locals also felt that the consultants were not fully integrated into the working community and did not exhibit the expected level of loyalty. Additionally, the locals were unhappy with the level of benefits the consultants received in comparison to the quality of their work input.

Second, there was evidence that consultants were sent to the JV without training to do business abroad, specifically in the area where they were sent to work. In such cases, particular challenges in communication with the local staff were pointed out when the consultants did not have enough knowledge of local culture and working traditions.

> When local managers complained, "T" HQ frequently replaced consultants. Afterwards, it became mandatory for consultants to participate in cultural training or a blitz course at HQ. (Observations).

Third, when the consultants were sent to JVs abroad, the HQ managers started to see the costs of using the consultants, which cost much more than the cost of the employees in HQ.

> I was informed that the primary responsibility of the consultants is to transfer knowledge from the headquarters to the joint ventures, as per the Management Agreement, and to train the local staff working in the joint ventures. We were aware that the expenses related to the consultants were quite significant. "The personal drive provided them the right to come home to Norway each second week. "T" rented a good apartment for the consultants. They had a high salary" (personal observation).

Finally, the company recognized at a later stage that consultants could not replace the need for managers.

> We were not so successful with the consultants. We thought that they could bring good competence to the company. They could not work with day-to-day control in our subsidiary without having the manager skills. They should be managers, not consultants… management is important in "T." Nevertheless, they were more consultants than managers … To get the best people was a problem—many of them were not tough enough to take the manager role. We did not get the best people from HQ. Cross-cultural issues were not necessary then. We required skilled managers who possess the ability to comprehend operations and exhibit competence. They used interpreters so long as the locals they worked with could not speak English. They could not choose the local staff; it was the decision by the local management "(former EVP in legal issues).

In summary, to the end of this phase, the need to increase shares in the JVs abroad to increase "T"'s influence in JVs started to be clear to the top managers of HQ—consultants in JVs needed to represent HQ interests in the BoD of subsidiaries. "T" needed more competence in international affairs with clear mandates to administrate the first international projects.

Phase 3 in the internationalization of "T" (2001–2005): "up or Out"

By the end of 1999, "T" had become one of the fastest-growing European companies that expanded beyond Norway's borders. "T" owned shares in joint ventures in Ukraine, Central Europe, Western Europe, and Asia, mainly in mobile operations. In this phase, the company has recognized the need for a formal internationalization

strategy, governance, and mechanisms to increase HQ influence over subsidiaries. The hope to build a strategic alliance with a big Swedish company to go quicker internationally and achieve a solid global position for the future failed in 1999.

> We Understood that we can manage to build up the international company alone. The failed merge encouraged us to be more professional and prioritize the international projects (Former CEO of "T").

In 2002, the newly appointed CEO and top management of "T" developed new strategic goals to further the company's international expansion. It was decided that "T" would shift its focus from having several small international operations scattered across different parts of the world to becoming a consolidated international operator with a more streamlined portfolio.

> After the merger with Telia fell through and our stock was listed on the NY stock exchange, we realized that we needed to take control of our operations in Eastern and Central Europe as well as Asia. To do this effectively, we needed to establish stronger influence and control and take on a more active role as an industrial investor. This meant changing the form of ownership in our subsidiaries, where I served as the former Director in T. International and EVP of Mobile Operations worldwide.

At the same time, the first challenges with the local partners in established JVs became a reality.

> It was difficult to deal with the local top managers and partners. Many of them had an agenda opposite the company's and our interests. Many of them were too close connections with the local authorities. For example, in one of the Eastern European companies, we had a majority position but not 100% ownership. However, controlling the operations was insufficient so long as the local managers were reported to the local CEO. When our consultants got the executive positions that we insisted on to avoid parallel reporting, they started reporting to the local CEO. However, even then, we did not have complete influence so long as the company had a local CEO whom we could not replace because of his connections to the political authorities in the country. Having the majority in the BoD, we cannot say that we had enough influence so long he Chairman of the BoD had strong connections with the authorities. We knew that the local authorities would not support us as a foreign investor if the conflict arose. We knew about the poor cord practice in the country (former EVP responsible for international mobile operations).

Hence, "T" initiated the process of becoming an international company with full control over its overseas operations. In addition, clear geographical priorities were formulated: Nordic countries, Eastern and Central Europe, and Asia. In order to achieve this strategy, it was decided to declare the main principle for this process related to ownership structure: to increase the ownership up to 100% to have the industrial and financial control or to leave (*out*) the company. This meant the consolidation of "the planted flags" in an international portfolio with an elaborated strategy "either up to the control or exit, i.e., up or out." Thus, this internationalization phase was crucial in terms of further developing "T" as an international actor. During the active process of merging and acquisitions (M&A), the number of JVs was reduced from 15 at the start of the internationalization process to 3 in Phase 3 (see Tables 1 and 2). At the same time, several Country offices opened with a clear mandate to support HQ and JVs in their operations. Country offices. The question of control started to

be an essential priority for "T" that followed the changes in many organizational structures of "T," such as establishing the international department that works just internationally, changing in mindset from "T" International to International "T," to strengthen the focus on the "internal internationalization."

> We, the top management of T., were at a leadership gathering to discuss T. International's new strategy. During the strategic process, everything changed—"T." International was transformed to International "T that followed big organizational changes—from how we work, think, and administrate the subsidiaries abroad to what kind of managers we should be. My first task as an HR EVP in "a new International "T" was to build up the new platform to trainee the international leaders, to build up the new governance" (former member of Group Executive Management, responsible for HR).

At the same time, in 2003, "T" Group launched for the first time in its history a common set of ethical standards defined by the "Code of Conduct" across all its business units. The new global reality brought "T" in the global business process, such as listing the company and finding a new identity adequate for the listed international company in growth.

As part of the aforementioned processes, "T" decided to change the status and role of expatriates. The use of consultants was no longer deemed sufficient as they did not represent the control issue. During the process of internationalization, the role of consultants changed. They were tasked with providing control and influence from the headquarters to newly established WOSs (Worldwide Operating Subsidiaries). The key executives' positions were appointed by "T" with a clear mandate to manage the subsidiaries and achieve the required performance level in accordance with the HQ's strategy. As a result, the Institute of Expatriates was formally established, where expatriates held executive positions. They had received formal responsibility for operations and reported to the BoD in WOSs. Due to their key position in "T" expatriates were closely connected to the executives in HQ. Some were members of the BoD and even the Chairman of the BoD. Expatriates were mostly Norwegians or Scandinavians.

Table 2 Mobile portfolio as March 31, 2000 (from T press-lease March 2000. "T" web site)

Company	Markets	Percentage-owned (%)
T Mobil	Norway	100
VIAG Interkom	Germany	10.0
Cosmote	Greece	22.0
DTAC	Thailand	40.0
Pannon GSM	Hungary	25.8
Esat Digifone	Ireland	49.5
DiGi.Com	Malaysia	30.0
Connect	Austria	17.5
Kyivstar	Ukraine	35.0
Grameen Phone	Bangladesh	46.4
Pro-Monte GSM	Montenegro	40.1

> It is crucial to have executives in our subsidiaries whom we know well and who share T's values. These executives should be familiar with the Norwegian culture abroad, and we should strive to provide the same standards and business culture as at our headquarters. Therefore, our expatriates should be both experienced executives and professionals who embody the DNA of our organization.

Most respondents connect the expatriate with the established institution that has an important role as a "girder" in subsidiary (SVP, responsible for the operations in Central Europe) to provide the key values from HQ and watch the processes in operations. The respondent explained the definition of "girder" in the following way:

> Expatriates play a crucial role in executive positions, actively involved in connecting subsidiaries and HQ, and contributing to governance. They represent the culture and norms of HQ and follow the business, strongly influencing employees in subsidiaries. As mediators, they understand the local employees and provide information back to HQ. This perspective comes from a senior manager who has worked as an expatriate in several countries.

The expatriates were tasked with establishing operational and behavioral control mechanisms in WOSs that corresponded with HQ's needs and goals. Operational control was used to report WOS performance to HQ, while behavioral control provided corporate governance. Thus, expatriates were essential in implementing corporate governance as a Code of Conduct. As one interviewee explained:

> We started to work with the Code of Conducts because we understood that having an ethical platform for our business abroad was important. The Code of Conducts should be signed by each WOS and JVs employee where "T" owners over 50%. A code of conduct is essential to implement to be understood as it should. We visited all subsidiaries, organized seminars, and explained the code of ethics and any ethical dilemmas. Norwegian executives had to shift their mindset from only focusing on business purposes to prioritizing issues of governance and values. They should be driven in the process—we worked hard, but not all of them understood it. One of the CEOs who expressed great interest in the process stated: If you can persuade my local management to think in accordance with the Code of Conduct, I will consider it the most significant contribution to the business purpose. The local employees should have the same standards in doing business as at home in Norway. Unfortunately, there were not all CEOs that thought like that (interview with the former EVP responsible for HR).

Thus, the expatriates were responsible for implementing the corporate rules at the beginning of the company's development. The ethical platforms were important to perform ethically; expatriates in the executive positions could insist on implementing and practicing Code of Conduct. Similarly, being Norwegians, the expatriates could show corporate governance principles by their examples.

In summary, expatriates were placed in executive positions in subsidiaries when HQ could strengthen control towards subsidiaries, and establishing the common corporate culture and rules became crucial for the further development of "T" as an international company. "T" needed to change the strategy for administrating the foreign subsidiaries. At the same "T" needed to go further in its internationalization process in implementing the principles of the common corporate governance, combining different companies into one group—"T" Group, developing a common culture, following further changes in the organization, where the role of expatriates was "tuned" again.

Phase 4 in the internationalization of "T" (2005–2014): "Different Companies—One Group"

During this time, "T" expanded its operations globally, with a focus on Asia, while also consolidating its presence in Europe. In 2005, "T" established itself as a rapidly growing mobile communications provider with a strong international outlook, and emphasized the importance of retaining industrial ownership. "T" has changed the name to "T" Group (in this research, it will be used "T") in order to underline the size of the company and a new strategy—"one Group—many companies" ("T" web site). The company pursued its expansion into international markets, focusing on developing new business opportunities from scratch (also known as "green fields")—an active M&A strategy targeting investments with high possibilities for growth. Hence, "T" strengthened its position in Asia and Europe, supporting "cluster-thinking" when countries of similar cultures that do business in and are located in the same geographic region were included in the portfolio.

In order to support the business activities of the companies and to develop further "cluster-thinking," the Country office has strengthened its position in providing the independent role as an extended link between the owner of the subsidiaries in Norway (HQ) and authorities in the cluster-region. As an example, the big Country office has been opened in Bangkok to administrate the activities in all Asian countries with an extensive stuff of Norwegians, local employees and people from different nationalities. In this connection, "T" can be defined as an MNC when "T" started structurally organized as an MNC: HQ administrates subsidiaries in clusters of 100% owned subsidiaries. At the same time, further internal internationalization has been continued—the new routines were established in order to have more focus on performance management: Business Reviews from "region/cluster" responsible to the CEO and the Executives in the Group, "region/cluster executives have got the institute of "TMPs"—top management support executive managers that are linked to the subsidiaries, BoD in subsidiaries and the professional teams in HQ to give the best practice support to the subsidiaries and provide the functions of influence and control from HQ. Strong internationalization of departments in HQ followed the changes in the corporate language, which started to be English. As a part of its internalization, "T" has extended the previous system of Code of Conducts and established the so-called "T" Way (TW)—a common for HQ and subsidiaries managerial process and a shared cultural platform. The TW was a system of corporate governance and common corporate rules. "T" started to create common documents as a framework for being a corporate citizen (Code of Conduct was the first common document for HQ and subsidiaries). Then, the overall image, the new visual images, the new branding strategy, and the whole concept of TW were finalized.

The expatriates started to play an essential role in understanding and implementing the corporate governance and corporate culture in subsidiaries abroad following TW to develop the common corporate governance and culture both for HQ and subsidiaries. Each expatriate who is now a CEO of T's subsidiary plays a significant role in the global business community, requiring professional, managerial, and individual skills. Most respondents connect the expatriates' institution with a critical

role to be a "girder" in a subsidiary to provide the key values from HQ and watch the processes in operations. Our informants emphasized the importance of expatriates being carriers of HQ's *DNA* to subsidiaries.

> Expatriates are essential to a company's success, according to a former Senior Vice President. They should hold executive positions and actively participate in projects, connecting the subsidiaries with the headquarters. Expats can influence local employees by representing HQ culture while following business norms. They act as mediators who understand the local employees and provide valuable information back to the headquarters.

> Expatriates are expected to be highly skilled and competent professionals who possess a deep understanding of the values and culture of the organization they represent. In other words, they should embody the DNA of the organization and be capable of implementing its strategies, practices, and values in subsidiary branches. … It is essential to have executives in subsidiaries that we know well and have «T»'s DNA … We need to provide the same standards and business culture as at HQ. They now have the freedom to select their own staff, and since they can communicate in English, it improves their communication. (the former EVP).

Local employees should practice working together with Norwegians in HQ and subsidiaries to understand the company's values and culture. This will help them gain a better understanding of the Group's network and improve their interaction with HQ and subsidiaries. Expatriates are expected to pay even more attention to the company's values and governance. The "Institute of Expatriates" is closely linked with the professional teams from the headquarters who are responsible for different skills. These teams can be utilized as high-level consultants or experts from the headquarters. These employees are not long-term executive expatriates, but rather temporary or short-term expatriates used by the executive expatriates for specific purposes, such as training the local staff or resolving particular issues. Simultaneously, the executive expatriates are closely linked with the top management in the development of strategy and strategic development "T." In addition, the expatriates are the subsidiaries' executives, providing operational excellence within the framework of the corporate strategy.

> When we first established the team of expatriates, we did not discuss DNA. This term came into use later with the establishment of the institution, referring to the highly skilled professionals who uphold T's values and governance. These professionals can be thought of as a professional pool.

The HQ should train/hire expatriates who can be carriers of the HQ's DNA. "T" has established a "DNA—pool" of expatriates to provide the right recruitment for the key positions. Executives at HQ established specific criteria for the selection of expatriates as CEOs in WOSs. One is the experience of working internationally. On the question of how the recruitment is happening, the former HR Executive VP explained:

> The top executives of "T" were responsible for recruiting CEOs in WOSs, while other expatriates were recruited by the WOS CEO in coordination with HR and the executive responsible for the region. The HR and regional executives placed candidate pictures on the wall for the CEO/CEOs to review. The Executive Board of "T" members walked from the picture to the picture and put their remarks- positive and negative comments- on the paper near

> the picture. After several rounds of discussion and opinion exchanges, the important criteria for the candidate was to have leadership experience and international work experience. There were, of course, other important criteria related to professional skills as well. This tool worked well, [but] sometimes a wrong person was appointed to the position—unfortunately, the personal skills were not paid much attention to. Nevertheless, we always managed to correct it. The last word was for the CEO (former HR Executive VP).

Another interview confirms the principle of the best practice that also impacts the process of being appointed as an expatriate.

> Proclaiming the idea of "different companies—one group," we meant both to have the common guidelines of doing business, our corporate governance and culture, but at the same time, we want to transfer the best practice from all subsidiaries to the common use. We can select what is the best not just for one country or region but for the whole group. The same goes for expatriates—we take the best practices they use and apply them to different subsidiaries. (former EVP, responsible for mobile international).

Several interviews described that the expatriates should still be Scandinavians.

> Foreigners who cannot represent the "T's DNA"—being good professional, cannot be expatriates, they did not understand the issue of culture, values, and governance influenced by their own culture (interviews with the employees in HQ worked a lot abroad both in Europe and Asia)

"T" started to include more Scandinavians by nationality employees in the "DNA pool" of expatriates.

> The company developed as a global entity, with many executives working in different positions worldwide. The top management has decided that all employees with the ambition to be appointed to executive positions either in HQ or in subsidiaries should have experience working internationally. It means there are more and more expatriates of different nationalities in the Group. They should adopt the same approach and transfer "T"'s governance DNA to subsidiaries' employees. (former EVP, responsible for HR)

At the same time, several negative comments related to the role of expatriates were mentioned.

First, the institution has become too powerful and different to get into.

> Expatriates have too much power. They are power-oriented people and want to be abroad and be moved from country to country. They are not returning to headquarters nor sharing information with their colleagues, but instead are constantly changing positions abroad. A negative culture has formed among local Norwegians, who cover up many things. Whistleblower culture is not developed well. Some suspicious episodes were ignored (former manager worked internationally in different countries).

Several respondents expressed confusion regarding the opaque and unclear process of recruiting individuals to be part of the "DNA pool of professionals. There is not much information about it in "T".

> They started to be an exclusive group, and it is almost impossible to come into this group..! (interview with an Employee).

Thirdly, "the private drive syndrome" can damage the institute of expatriates. The local staff have a negative reaction towards the expatriates' benefits, which are perceived as more favorable than what is typical in the local area. The expatriates have luxury around them with private drives, huge apartments, and house help. Many are unwilling to return to Norway and "change the chairs" from country to country. In summary, "T" needs to develop the organization as an MNC—a complete international focus on HQ and subsidiaries that change the role of expatriates. Expatriates became the "DNA—pool of professionals" from different nationalities, providing the best practice across the Group based on the implemented Common Corporate governance.

5 Conclusion

In this paper, we examine how the control mechanisms of multinational corporations (MNCs) change as they expand internationally. Specifically, we focus on the perceptions of top managers in the MNC's headquarters regarding the effectiveness of expat-control processes during different phases of internationalization. We further explore how these perceptions influence the configuration of HQ's expat-control mechanisms. Notably, this study has addressed two research questions:

(1) whether and how has the configuration of expat-controls changed during the different phases of an MNC internationalization process? and
(2) how can those changes in the configuration of expat-controls be attributed to changes in the top managerial perceptions of the output of expat-control in terms of HQ achieving influence over subsidiaries?

Table 3 summarizes the empirical findings. Based on the description in the empirical section, our first finding is that the expat control has been "tuned" to handle different challenges during the internationalization process. The expatriates had quite different roles in the process of internationalization. Those who worked in "T" when the process of internationalization started used the definition of "passionate ambassadors," which then changed to "consultants." Later, expatriates became a "DNA—pool of professionals in the late stage of internationalization that also strengthened their position in WOS and HQ (Table 4).

Tuning expat control during internationalization: from passionate ambassadors to professionals

The empirical evidence shows that the evolution of the expat-controls from being an ambassador to consultant to a professional underlined the different sets of skills and tasks in their roles. The modern expatriate is expected to be more of a manager and be in top executive positions to provide the direct link between HQ (owner) and the subsidiary. Expatriates thus became an institution in "T" supporting the execution of routines, rules, traditions, status, and behavior. There were several informal definitions of expatriates in "T" that describe their role as more nuanced: "HQ's

Table 3 Mobile portfolio as 2014 (based on the information form T web site)

Company	Markets	Percentage-owned (%)
T Mobil	Norway	100
T Sweden	Sweden	100
T Denmark	Denmark	100
DTAC	Thailand	100
DiGi.Com	Malaysia	49
T Myanmar	Mayanmar	100
Grameen Phone	Bangladesh	55.8
T Pakistan	Pakistan	100
Uninor	India	100
Hungary	Hungary	100
T Montenegro	Montenegro	100
T Serbia	Serbia	100
T Bulgaria	Bulgaria	100
VimpelCom	HQ Netherland	33

DNA" and a "girder that carries out both the operations and governance." These definitions linked the role of expatriates closer to HQ. At the same time, being "a girder" in an organization gives the expatriates a special position—to implement the strategy, ideas, and culture from HQ and adapt it to the local context "T." Some negative opinions are linked to the role of expatriates related to the frequent rotation of expatriates, such as that they are changing the chairs and not coming back to HQ to share the competence. This creates a negative attitude toward the expatriates in HQ—coming in a "DNA pool of professionals" is not transparent and unclear [1]. Expatriates started to be rich because of the good packages. The local staff reacted to the benefits that expatriates have towards them. Several interviews described that the expatriates should be Scandinavians. There were many bad examples with expatriates—foreigners who cannot represent the "T's DNA"—being good professionals, and they did not understand the issue of culture, values, and governance influenced by their own culture.

5.1 Changes in the Expat-Controls: Perceived "Deprivation of Control"

Our second finding is that the role of expatriates has changed as a response to a notion of "deprivation of control" (see Fig. 6) experienced by the top managers at HQs.

We analyzed the perceptions of individual managers we interviewed regarding the outcome of expat-control process in various stages of internationalization. Our

Table 4 Summary of empirical findings

Phases of internationalization	Phase 1 1992–1996	Phase 2 1996–2001	Phase 3 2001–2005	Phase 4 2005–2014
Internationalization processes	"Small company—small international steps"	"The "Viking strategy"	"Up or Out"	"Different companies—one Group"
Strategic challenges faced by top managers at HQ related to managing subsidiaries	– To develop individuals with international experience – JV is a preferable form; BoD is mostly the minority – Code of Conduct (CoC)is not on the agenda	– To develop international affairs with clear mandates to administrate subsidiaries – JV is preferable but challenging – The CoC is created in HQ	– From JV to WOS based – CoC is extended to TW as a common platform	– To develop an MNC with a complete international focus – WOS with 100% (only a few exceptions) – T Way/CoC systematically implemented in all subsidiaries
Expat-control	Via "passionate ambassadors"	Via individual consultants to local executives	Via "girder" in subsidiaries, only Norwegians in the top positions	Via DNA pool of professionals, people of different nationalities
Perceived HQ-subsidiaries influenced by top managers	"Discomfort" because "T"'s managers lacked international experience and financing in order to take significant steps internationally	"Discomfort" because "T"'s managers lacked the financial means to go for WOS. Many negative experiences with minority ownership and use of consultants	"Discomfort" because it is difficult to establish a common platform for companies under the same "umbrella" with so many different traditions and cultures	"Discomfort" because of negative attitude towards expatriates; Scandinavian or international expatriates

findings suggest that HQ managers experienced a great deal of discomfort when describing how the use of expat controls contributed to improving their level of influence over subsidiaries during different internationalization stages, as per [7]. There seemed to be a disagreement between the top managers at headquarters regarding how much control they actually had over their subsidiary companies, versus the extent to which the behavior and actions of expatriates could improve this level of control. This disagreement caused discomfort among the parties involved and highlighted the need for a better expat control process.

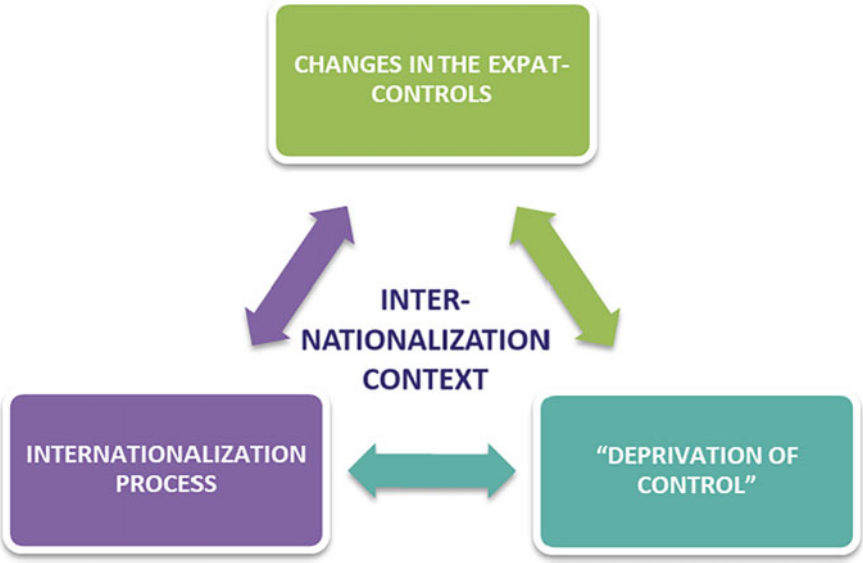


Fig. 6 Findings of the study—"deprivation of control"

Developing an increased international presence has required HQ to rethink its actual state of influence over subsidiaries and the use of expat control. This rethinking process, as we interpret it when analyzing narratives of top managers, resembles a search for/a desire to achieve full influence over subsidiaries by experimenting and tuning expat-controls towards the different contingencies and new antecedences. However, we also sense expressions of suffering from the fact that HQ managers, irrespective of what they have done, could never achieve total influence by reconfiguring expat controls. Thus, "discomfort" with lack of influence has never fully disappeared because each internationalization stage presented unique challenges that a particular configuration of expat-control has fully solved. In this sense, the evolution of the expat-control system, from "individual consultants" towards "a DNA" pool, can be understood as driven by this particular top managerial perception to get rid of this "discomfort". This state of "discomfort" can be termed "deprivation of control"—a shared mental state of top managers in MNC T that signifies their continuous inability to secure the appropriate control outcomes to achieve a high level of influence over subsidiaries. Table 1 demonstrates that top managers developed a sense of "discomfort" over time due to inconsistencies between the internationalization process and its priorities, the use of expat-control as a means of control, and the outcomes of the control process. Thus, "deprivation of control" refers to a situation in internationalization where the manager is unable to design appropriate control mechanisms and, as a result, fails to achieve the desired level of influence over subsidiaries. Tuning configurations of expat-control during the internationalization process was both a response to the different challenges of internationalization they experienced and a

quest to eliminate this control deprivation. Regarding the "illusion of control" literature, managers of MNC T seemed to have no illusions that they experienced a lack of influence because of different imperfections of expat-controls. Still, this disillusion does not help them in their struggle to design an appropriate expat-control system to secure an appropriately high level of influence. Therefore, the results of the study suggest that companies, particularly during the initial phases of their internationalization, should develop management systems to regulate their subsidiaries and refine their internationalization strategies. Achieving complete control over subsidiaries may be impossible, so it's crucial to define acceptable levels of control. This can give a more meaningful discussion around what control tools can achieve a particular level of influence and control rather than the organization risks falling into the "derivation of control." First, this paper contributes to the literature on management control systems in change, demonstrating how the evolution of management control systems can be understood as the result of top managers' psychological and cognitive perception processes. Thus, we answer Hall's call [5], aiming to explore the use of psychology theory in studying organizational management control. Second, we contribute to the literature on expats as a control mechanism in internationalization settings. Previous studies tend to describe the use of expat control as a static process and focus too much on, e.g., the role of staffing policies in selecting expatriates and the necessity to choose a manager's technical and managerial skills and expertise. Our study differs from the previous studies about the role of expatriates by showing its dynamic evolution in the context of the internationalization process.

References

1. Roddvik, I.N.: Deprivation of control: A driving force to gain influence during the internationalization process of MNC (a case study: a Norwegian multinational corporation) (PhD thesis). Nord University, Bodø, pp. 336 (2019). https://core.ac.uk/download/351642206.pdf
2. Gupta, A., Shrivastava, R., Jain, J.: Emerging trends in database and its applications in MNC's. Int. J. Educ. Manage. Eng. (IJEME) **13**(4), 33–41 (2023). https://doi.org/10.5815/ijeme.2023.04.05
3. Burns, J., Scapens, R.: Conceptualising management accounting change: an institutional framework. Manag. Account. Res. **11**(1), 3–25 (2000)
4. Covaleski, M.A., Dirsmith, M.W., Weiss, J.M.: The social construction, challenge and transformation of a budgetary regime: the endogenization of welfare regulation by institutional entrepreneurs. Acc. Organ. Soc. **38**(5), 333–364 (2013)
5. Hall, M.: Realizing the richness of psychology theory in contingency based management accounting research. Manag. Account. Res. **31**, 63–74 (2016)
6. Kahn, W.: Psychological conditions of personal engagement and disengagement at work. Acad. Manag. J. **33**, 692–724 (1990)
7. Bourmistrov, A., Kaarbøe, K.: From comfort to stretch zones: a field study of two multinational companies applying "beyond budgeting" ideas. Manag. Account. Res. **24**(3), 196–211 (2013)
8. Dermer, J.D., Lucas, R.G.: The illusion of managerial control. Acc. Organ. Soc. **11**(6), 471–482 (1986)
9. Seal, W., Mattiome, R.: Controlling strategy through dialectic management. Manage. Account. Res. **25**, 230–243 (2014)

10. Scheytt, T., Soin K., Metz, T.: Exploring notions of control across cultures: a narrative approach. Eur. Account. Rev. (2010)
11. Chalos, P., O'Connor, N.G.: O Determinants of the use of various control mechanisms in US–Chinese joint ventures. Acc. Organ. Soc. **29**, 591–608 (2004)
12. Delios, A., Bjorkman, I.: Expatriate staffing in foreign subsidiaries of Japanese multinational corporations in the PRC and the United States. Int. J. Human Resourc. Manage. **11**(2), 278–293 (2000)
13. Martinez, J.I., Jarillo, J.C.: The evolution of research on coordination mechanisms in multinational corporations. J. Int. Bus. Stud. (1989)
14. Kira, M., Korpelainen, E.: Sustainable work in the comfort and discomfort zones of work. Paper presented at EGOS 2012 Meeting, July (2012)
15. White, A.: From Comfort Zone to Performance Management. White & MacLean Publishing, Baisy-Thy, Belgium (2009)
16. Van Eck, N.J., Waltman, L.: Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics **84**(2), 523–538 (2010)
17. Van Eck, N.J., Waltman, L., Dekker, R., Van den Berg, J.: A comparison of two techniques for bibliometric mapping: multidimensional scaling and VOS. J. Am. Soc. Inform. Sci. Technol. **61**(12), 2405–2416 (2010)
18. Quattrone, P., Hopper, T.: A "time" space odyssey': management control systems in two multinational organisations. Acc. Organ. Soc. **30**, 735–764 (2005)
19. Clemmons, S., Simon, S.J.: Control and coordination in global ERP configuration. Bus. Process. Manag. J. **7**, 205–215 (2001). https://doi.org/10.1108/14637150110392665
20. Taylor, S., Levy, O., Boyacigiller, N., Beechler, S.: Employee commitment in MNCs: Impacts of organizational culture, HRM and top management orientations. Int. J. Hum. Resour. Manag. **19**, 501–527 (2008)
21. Giacobbe, F., Matolcsy, Z.J: An investigation of wholly-owned foreign subsidiary control through transaction cost economics theory. Account. Finance **56**, 1041–1070 (2016)
22. Rao, M.T., Brown, C.V., Perkins, W.C.: Host country resource availability and information system control mechanisms in multinational corporations: an empirical test of resource dependence theory. J. Manag. Inf. Syst. **23**, 11–28 (2007)
23. Distelhorst, G., Shin, J.-E.: Assessing the social impact of corporations: evidence from management control interventions in the supply chain to increase worker wages. J. Account. Res. **61**, 855–890 (2023). https://doi.org/10.1111/1475-679X.12472
24. Narayanan, V., Boyce, G.: Exploring the transformative potential of management control systems in organisational change towards sustainability. Account. Audit. Account. J. **32**, 1210–1239 (2019). https://doi.org/10.1108/AAAJ-04-2016-2536
25. Hoque, Z., Chia, M.: Competitive forces and the levers of control framework in a manufacturing setting: a tale of a multinational subsidiary. Qual. Res. Account. Manag. **9**, 123–145 (2012). https://doi.org/10.1108/11766091211240351
26. Kapiyangoda, K., Gooneratne, T.: Institutions, agency, culture and control: a case study of a multinational operating company. J. Account. Organ. Chang. **14**, 402–428 (2018). https://doi.org/10.1108/JAOC-07-2017-0056
27. Xi, K.K.: Integrating the global with the local: performance measurement in multinational corporations. Transl. Corp. Rev. **3**, 54–68 (2011)
28. Bjerregaard, T., Klitmøller, A.: Conflictual practice sharing in the MNC: a theory of practice approach. Organ. Stud. **37**, 1271–1295 (2016)
29. Helin, S., Sandström, J.: Resisting a corporate code of ethics and the reinforcement of management control. Organ. Stud. **31**, 583–604 (2010)
30. Cooper, D.J., Ezzamel, M., Robson, K.: The multiplicity of performance management systems: heterogeneity in multinational corporations and management sense-making. Contemp. Account. Res. **36**, 451–485 (2019). https://doi.org/10.1111/1911-3846.12416
31. Hidayat, T., Mahardiko, R., Rosyad, A.: Forecasting of Indonesian digital economy based on available new start-up. Int. J. Inform. Eng. Electron. Bus. (IJIEEB) **15**(2), 11–19 (2023). https://doi.org/10.5815/ijieeb.2023.02.02

32. Lytvynenko, V., Kryvoruchko, O., Lurie, I., Savina, N., Naumov, O., Voronenko, M.: Comparative studies of self-organizing algorithms for forecasting economic parameters. Int. J. Modern Educ. Comput. Sci. (IJMECS) **12**(6), 1–15 (2020). https://doi.org/10.5815/ijmecs.2020.06.01
33. Fagerlin, W.P., Lövstål, E.: Top managers' formal and informal control practices in product innovation processes. Qual. Res. Account. Manag. **17**, 497–524 (2020)
34. Aliyev, A.: Development of models of manufacturing processes of innovative products at different levels of management. Int. J. Inform. Technol. Comput. Sci. (IJITCS) **11**(5), 23–29 (2019). https://doi.org/10.5815/ijitcs.2019.05.03
35. Aliyev, A.: Technologies ensuring the sustainability of information security of the formation of the digital economy and their perspective development directions. Int. J. Inform. Eng. Electron. Bus. (IJIEEB) **14**(5), 1–14 (2022). https://doi.org/10.5815/ijieeb.2022.05.01
36. Yu, M., Bai, H.: Study on influencing factors of regional economy based on multilevel model. Int. J. Math. Sci. Comput. (IJMSC) **9**(4), 29–43 (2023). https://doi.org/10.5815/ijmsc.2023.04.04
37. Groot Tom, L.C.M., Merchant Kenneth, A.: Control of international joint ventures. Account. Organ. Soc. **25**, 579–607 (2000)
38. Dutta, D., Beamish, P.W.: Expatriate managers, product relatedness, and IJV expatriate managers, product relatedness, and IJV performance: a resource and knowledge-based perspective. J. Int. Manag. **19**, 152–162 (2013)
39. Fedushko, S., Mastykash, O., Syerov, Y., Peracek, T.: Model of user data analysis complex for the management of diverse web projects during crises. Appl. Sci. **10**, 9122 (2020). https://doi.org/10.3390/app10249122
40. Bjørnenak, T., Kaarbøe, K.: Dynamic management control—what is that? In Norwegian. Dynamisk Styringssystemer – Hva er Det? MAGMA **05**, 22–30 (2011)
41. Blenko, M., Mankins, M., Rogers, P.: The decision-driven organization. Harv. Bus. Rev. **88**(6), 55–62 (2010)
42. Burchell, S., Club, C., Hopwood, A., Hughes, J., Nahapiet, J.: The roles of accounting in organizations and society. Acc. Organ. Soc. **5**, 5–27 (1980)
43. Burdett, J.: TQM and re-engineering: the battle for the organization of tomorrow. TQM Mag. **6**(2), 7–13 (1994)
44. Giraud, F., Langevin, P., Mendoza, C.: Justice as a rational for the controllability principle: a study of managers' opinions. Manag. Account. Res. **19**, 32–44 (2008)
45. Gunn, B.: The paradigm shift in university management. Int. J. Educ. Manag. **9**(1), 28–40 (1995)
46. Howcroft, D.: Spreadsheets and the financial planning process: a case study of resistance to change. J. Account. Organ. Chang. **2**(3), 248–280 (2006)
47. Jensen, M.: Paying people to lie: the truth about the budgeting process. Eur. Financ. Manag. **9**(3), 379–406 (2003)
48. Marginson, D., Ogden, S.: Managers, budgets and organizational change: unbundling some of the paradoxes. J. Account. Organ. Chang. **1**, 45–62 (2005)
49. Marginson, D., Ogden, S.: Coping with ambiguity through the budget: the positive effects of budgetary targets on managers' budgeting behavior. Acc. Organ. Soc. **30**, 435–456 (2005)
50. McCarthy, G., Lane, A.: One step beyond: is the public sector ready to let go of budgeting? J. Financ. Manage. Public Serv. **8**(2), 23–49 (2009)
51. Seijts, G., Lathem, G.: Learning versus performance goals: when should each be used? Acad. Manage. Executives **19**(1), 124–131 (2005)
52. Tanlu, L.J.: Essays on Forecasting. DBA thesis, Harvard University, Graduate School of Business Administration, pp. 51–64 (2009)
53. Kraus, K., Strömsten, T.: Internal/Intrer-firm control dynamics and power—a case study of the Ericson-Vodafone relationship. Manage. Account. Res. **33**, 61–72 (2016)

Management in Family Business in the Slovak Republic

Ľubomíra Strážovská and Branislav Borecký

Abstract Family businesses play an essential role in the national economy of every country. They are formally incorporated into small, medium, or large enterprises. The family business form is the oldest form of business in the world. For family businesses to be able to function well and do business, they must have quality management and marketing management. Every business needs functional management to run a business and produce goods or provide services. The aim of the chapter is to provide comprehensive knowledge from the management theory of small, medium, and family businesses and to understand the phenomenon of family businesses and the importance of quality management in them. We chose analysis and synthesis, deduction, and current legislation, which was created in 2023, as the methods for their investigation. The results of the chapter will show the importance and influence of management on the success of family business management.

Keywords Family businesses · Management theory · Marketing management · Small and medium-sized enterprises · Family business management · Business legislation

Ľ. Strážovská (✉) · B. Borecký
Faculty of Management, Comenius University Bratislava, Odbojárov 10, Bratislava, Slovak Republic
e-mail: lubomira.strazovska@fm.uniba.sk

B. Borecký
e-mail: branislav.borecky@fm.uniba.sk

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2024

P. Štarchoň et al. (eds.), *Data-Centric Business and Applications*, Lecture Notes on Data Engineering and Communications Technologies 213,
https://doi.org/10.1007/978-3-031-62213-7_6

1 Introduction

1.1 Relevance

A long-term problem for solving the situation of family businesses in Europe context is the fact that in most European countries there is no definition family business within the framework of business legislation. At the legal level order, family businesses are only mentioned in five European countries (Italy, Austria, Croatia, Romania, and Malta), but between these countries, there is no uniform approach to family businesses [1]. Moreover, on the level professional literature [2, 3], various measures and discussions exist in the European area up to 90 different definitions that do not have a common basis. That makes it impossible any meaningful international comparison of statistics on numbers and situation family businesses in Europe. This also has an impact on the situation in which the family businesses are not targeted in most countries with any targeted form of support by public institutions. The only European country with a separate the law dealing with family businesses is Malta, which adopted the Act on family business in 2016. The business process consists of several activities that the business owner must carry out. Especially family businesses and their owner or owners must manage their business so that it survives in a hectic competitive environment [4] (Table 1).

One of the activities of the owner is also marketing management and its activities. Management is a management process in which the owner carries out various activities. The management is characterized by its direct entrepreneurial activity and orientation towards achieving profit. In other words, according to the Commercial Code, a company does business to make a profit [5].

Table 1 The ten oldest family businesses in the world, name year, industry

1. Kongo Gumi Japan, 578 Kongo Construction
2. Hōshi Ryokan Japan 718 Hōshi Hospitality
3. Château de Goulaine France 1000 Goulaine Winery
4. Pontificia Fonderia Marinelli Italy 1040 Marinelli Bell making
5. Barone Ricasoli Italy 1141 Ricasoli Winery
6. Barovier & Toso Italy 1295 Barovier and Toso Glassware
7. Hotel Pilgrim Haus Germany 1304 Andernach Hospitality
8. Richard de Bas France 1326 de Bas Stationery
9. Torini Firenze Italy 1369 Torrini Goldsmiths
10. Antinori Italy 1385 Antinori Winery

Source Own processing

Small and medium-sized and its sub-member family businesses must apply a high-quality management as well as marketing process to survive turbulent competitive relations in the business environment. Marketing management is an extremely important activity both for the company and for target groups of customers.

We emphasize once again that not only large enterprises, but also small and medium-sized enterprises need effective management theory as well as practice. Perhaps the only difference is that in small businesses individual management activities are performed by the owner or founder of the business himself. In large companies, it is easier because these activities are delegated to other people [6]. Every business needs quality management to do business and produce goods or provide services. Developed democratic states support business in the form of various support programs. Because it is small, medium, and family businesses that create employment and value for every economy.

Since the national economy of the Slovak Republic consists of ninety-eight percent of small and medium-sized enterprises (including family enterprises), it is necessary to characterize them. Finally, in the field of management theory and practice, we will focus our attention on the relationship of management to family businesses.

Small and medium-sized enterprises become the subject of research in theoretical workplaces, an area of interest for the state and a specific interest of the business community [7].

Gradually, small, and medium-sized enterprises, based on public interest, research and results in practice, are attributed several advantages, namely:

(a) small and medium-sized enterprises and family businesses are the most important element of national economies.
(b) small and medium-sized family businesses have an irreplaceable role in the dynamic development of countries with advanced market economies [8];
(c) small and medium-sized family businesses are highly adaptable to market requirements and especially demand;
(d) small and medium-sized family businesses have an innovative function;
(e) small and medium-sized family businesses satisfy even the most demanding customer requirements, they are flexible;
(f) small and medium-sized enterprises, family businesses create new jobs and thereby significantly influence the development of employment in the state;
(g) many other positive properties are attributed to them [9].

1.2 Goals and Objectives

Despite many contributions in the field of family businesses, very few contributions or studies deal with management and family businesses.

The aim of this work is to contribute to a better understanding of the mechanisms that are essential for the management and marketing management of family businesses. From the history of existing family businesses, we know that for a business to function well, it must have well-secured and organized management.

Focusing on this form of entrepreneurship allows for an understanding of the complexities of management and can help researchers in the disciplines of management science as well as managers and other actors in organizations to better understand the specific capabilities that organizations must achieve to function well.

This chapter is structured as follows. First, we provide an overview of management theory and management marketing, which form the basis for management science. Then we will present examples from the management of domestic and foreign family businesses. Finally, we discuss the extent to which management is important for family businesses. The chapter closes with a summary and its own contributions.

2 Theoretical and Conceptual Background

2.1 The Foundation for a Family Business and Management

Management represents one of the most important activities of running a business or a business owner. The success of the company often depends on the skill and skill of the company's management, i.e., its management.

Management represents the management of organizations existing in the conditions of a market economy, which is characterized by sufficiently flexible competitive activity, price mechanisms as well as effective allocation of available resources. Knowledge of management is essential in business activity, while management is not only used for business, but is also applied in the non-business sphere. As we mentioned, management is used in the public sphere as well as in private non-profit organizations [10].

The term management has three basic meanings:

- Management as a practical activity;
- Management as a theory or scientific discipline;
- Management as a special group of people.

Management as a practical—everyday activity and represents a type of work or a set of activities that managers perform or must perform to achieve a goal. As we mentioned, the business goal of every business according to the Commercial Code is to make a profit.

Management means coordinating the activities of other people—i.e., employees, to achieve the company's goal [11].

Management, as a scientific field or scientific discipline, represents a logical, systematic, constantly researching set of knowledge about the principles, methods, and procedures of management, and they are developed based on empirical knowledge that can be taught.

The world-famous author and recognized management expert Peter Drucker, who is considered the founder of management theory, says that: "… management is no less a science than medicine." In both cases, it is a scientific discipline. Management is an

interdisciplinary scientific field and deals with the purposeful activity of people, and its mission is to create a management methodology with an emphasis on achieving the effectiveness of this activity in relation to a predetermined goal. It is advisable to supplement the quantifiable definitions with certain qualitative characteristics about entrepreneurs (an entrepreneur is also a manager) in general, as stated in the literature [12, 13]. To be an entrepreneur and a quality manager, one needs to be someone who:

(a) likes to manage, innovate, has self-confidence, is enthusiastic and tenacious, likes to solve problems, fights against routine, works efficiently and with low costs;
(b) can gather and coordinate economic resources and apply them in a practical and efficient manner in the market;
(c) acts with regard to personal advantages such as prestige, ambition, independence;
(d) he knows how to manage the economic situation and his business can make a profit.

Small, medium-sized and family businesses are mostly privately owned and managed businesses that do not have a dominant position in the chosen field of business [14].

It should be added to the above that a small and medium-sized enterprise can be created and operated by self-employed persons, but also by commercial companies employing up to 249 employees. If we choose the number of employees as a criterion, as mentioned above, we recognize the following business entities:

1. self-employed—often one natural person or family, which may or may not be registered in the Commercial Register, it may also be micro-enterprises;
2. small businesses with up to 49 employees—these can be natural persons who may or may not be registered in the Commercial Register, but also commercial companies (legal entities) that are registered in the Commercial Register;
3. medium-sized enterprises with 50–249 employees in the form of commercial companies, but also in the form of cooperatives and currently also in the form of state enterprises. These business entities must be registered in the Commercial Register [15].

The individual criteria provide different views and perspectives of getting to know small and medium-sized entrepreneurs and family businesses. All criteria are significant in terms of understanding their status and development process.

The activities of small and large enterprises are interconnected. The existence of many small businesses often depends on the management of large organizations that buy their goods and services or act as marketing intermediaries for their finished products. In addition, large trading companies often depend on small businesses as providers of specialty products and services; as well as testers of high-risk initiatives that large enterprises can then put into production. The SME sector is critical to the health of the economy. Also, the management or leadership of large and medium or small enterprises can be linked [16].

In most countries, there is no single official description of small and medium-sized entrepreneurs or businesses. There are several quantifiable characteristics that

are also used for taxation purposes, respectively for many other relationships, for example the support of business entities by the state [9].

The public's views on small and medium-sized enterprises have changed and there has been a renewed interest in this type of enterprise. It can be assumed that it was, in a certain way, a restoration of the traditions of small and medium-sized businesses after the Second World War. The definition of entrepreneurs, businesses, and entrepreneurship in three basic characteristics is given under the name Bolton. It is named after the place where the conference was held in 1971, where the foundations of modern theoretical research on small and medium-sized enterprises in Europe were laid. These are the following characteristics:

1. small and medium-sized enterprises have a relatively small market share and practically cannot significantly influence the market in any way.
2. small and medium-sized enterprises are managed by owners (property management)—entrepreneurs, families of owners, respectively by co-ownership, and not mediated through a formal management structure.
3. small and medium-sized enterprises are independent enterprises; they do not form part of another larger enterprise [17].

The owners—entrepreneurs also form the management of the company. A great development of small and medium-sized and family business entities in Slovak conditions was recorded in 1991/1992, while their birth was conditioned by several facts:

1. the gradual disintegration of large state-owned enterprises in the process of the first wave of large-scale privatization and the emergence of a greater number of small and medium-sized enterprises,
2. return of property to citizens as part of restitution,
3. liberalization of trade relations and the creation of a larger number of small and medium-sized enterprises with foreign equity participation [18].

Kita et al. states that, from a quantitative point of view, the term small and medium-sized enterprises and family businesses also includes freelancers from all industries, if they do not exceed a certain size. Statistical determination of the size of the enterprise causes problems and therefore a suitable size indicator is needed [19].

Technical-quantitative criteria have several disadvantages, for example limited informative value. He points out that with the same number of employees, the company's turnover can fluctuate considerably even in the same industry, due to differences in the structure of orders, in the quality of management, capacities, capital and wage demands or productivity. The differences are even greater if companies from different industries are classified [20].

For the size distribution of small and medium-sized enterprises, it is most often used due to simplicity, compatibility, and practicality—the number of employees and turnover.

For the field of trade and services—quantitative criteria have a different but extraordinary meaning. As stated by Nováčková and Vnuková, the legislation of

the European Union uniformly defined the concept of small and medium-sized enterprises. As a quantitative upper limit, small and medium-sized enterprises have:

(a) less than 250 employees,
(b) annual turnover of a maximum of 40 mil. euro,
(c) can show a balance of no more than 27 mil. euro [21].

Within this classification, businesses are further differentiated according to the number of employees. They are divided into the smallest, i.e., micro-enterprises (1–9 employees), small enterprises (10–49 employees) and large enterprises (more than 249 employees) [22].

2.2 Other Characteristics of Small and Medium-Sized Enterprises and Family Enterprises from the Point of View of Management

Other characteristics of small and medium-sized enterprises from the point of view of management are as follows:

(1) Small and medium-sized enterprises are characterized by the possibility of increasing employment, acting as a source of employment opportunities. Small and medium-sized enterprises provide numerous opportunities for employment, thereby contributing to solving social problems. They make it possible to use local labor resources, respectively to employ persons with reduced working capacity [23].
(2) Small and medium-sized enterprises gradually created and are creating prerequisites for more effective use of people's unique abilities, knowledge, and work habits. An entrepreneur or manager may have interesting ideas regarding the improvement or creation of new products, processes and services that are not supported by large enterprises. Small and medium-sized enterprises are frequent product innovators [24].
(3) The importance of small and medium-sized enterprises can also be seen in the management of relationships with customers, suppliers, and employees—they have direct contact with them. They can also be successful because the owner-manager knows the company's customers and their specific needs, which he is trying to satisfy. Sales consist of both quality and quantity, relationships, and price. Communication between management and employees is immediate and not mediated, which helps improve management [25].
(4) Small and medium-sized enterprises have created simple managerial management structures and do not use bureaucratic procedures in management, which allows them to be more flexible both inside and outside the company. This is related to the fact that decision-making in small and medium-sized enterprises is a matter for a small number of people. The rules for working in small and medium-sized enterprises are less strict. They do not need large investments for

their activity, it allows them to react more easily and quickly to changing market conditions, or to modify products. They have prerequisites for flexible response to fluctuations in demand [26].

(5) Research carried out between 2010 and 2018 by the Slovak Business Agency (former National Agency for the Development of Small and Medium Enterprises) found that their owners or managers have a lot of freedom in decision-making, which supports their motivation to do business [27].

The managerial goals and functions of small and medium-sized enterprises are extremely important for family businesses. Small and medium-sized enterprises mainly focus on achieving two types of management goals:

1. Management goals are profit-oriented, businesses aim to achieve the greatest possible profit in the shortest possible time (as well as large enterprises).
2. Management goals are oriented primarily to the market and only secondarily to profitability—the primary goal of the company is to achieve a certain market share and the resulting long-term growth [4].

3 Complexity and the Concept of Family Businesses

In the following text, we discuss the diversity of definitions of family businesses and the new law to support family businesses in Slovakia.

3.1 Definitions of Family Businesses in Slovakia and Abroad

Family business and to capture legal relations where family members participate in the work in the family plant [28]. Among other things, the people involved in its management and not the business itself are important for a family business.

From 2019, by Resolution of the Government of the Czech Republic no. 330 of May 13, 2019, defined the term family business in the Czech Republic. The approved definition refers to a family business as a family business corporation or a family business [25, 29]. In a family business, it is important to determine exactly which family members can participate in it. Based on the accepted definition, individual species are divided as follows:

1. "A family business corporation is a business corporation in which more than half of the partners are members of one family and at least one member of this family is its statutory body, or in which members of one family directly or indirectly exercise the majority of voting rights and at least one member of this family is a member of the statutory body of this business corporation. A family business corporation is also considered a business corporation in which most voting rights are exercised in favor of one family by a fund manager or a trust fund manager,

if at the same time at least one member of this family is a member of the fund's statutory body or a trust fund manager.

2. A family business is a business in which at least two members of one family participate with their work or property and at least one of the members of this family holds a trade or other similar authorization or is authorized to do business based on another reason [30].
3. For the purposes of a family business, spouses or partners working together or with at least one of the spouses or partners and their relatives up to the third degree, persons with spouses or partners up to the second degree, and persons related in the direct line or siblings are considered members of one family. If there is a person among them who does not have full legal capacity, they are represented during voting by their legal representative, if they are minors, otherwise by their guardian."
4. Several non-binding definitions of family business have been created in the Republic of Poland. Many initiatives have been trying for many years to enforce this concept in binding legal regulations. Definitions are based on features that consider a family business as a business in which mutually related persons make strategic decisions and the aim of their activities is to pass the family business on to the next generation. In a family business, which is considered an economic unit with a registered legal form, at least two family members are involved in the management of the business and most of the capital of the family business is in the hands of the family. Several generations of the family are involved in the business. These joint entrepreneurs must be perceived as a family business and their main source of income is the income obtained from the business activity of the company [31, 32].

The Republic of Hungary also does not have an approved family business law or a legal definition of a family business. In the provision of subsidies for family farms, there was a partial definition of the term family farm. An active agricultural unit of a certain size is considered a family farm [33, 34]. The economic unit in question is either owned by the family, leased by the family, or used based on another title. It is essential that, in addition to the farmer (family member), at least one other family member is employed full-time.

Another definition of a family business was created by the Budapest Business Development Center LAB at the Budapest University of Economics. According to this generally accepted definition, a family business is a business in which the family has an ownership stake of more than 51% or most voting rights are in the hands of the family, and this ensures their full control over the management of the business [15, 35].

There are different characteristics of family businesses based on different characteristics:

(a) the founder or owner of the business considers his business to be a family business;
(b) the goal of a family business is the reconciliation of management goals: management, business, ownership and family goals;

(c) the family has the main influence on the ownership and management of enterprises;
(d) active involvement of family members in business;
(e) due to the connection between family and business, there is a typical emotional component in business;
(f) founders must be good managers to be able to organize all management activities in the company;
(g) The founders have their own vision to build a stable business in order to pass it on to the next generation;
(h) Management goals of family businesses are long-term;
(i) The development of the family business is sensitively intertwined with the development of the family;
(j) The family business creates a family atmosphere in the internal structures of the company and in the workplace of the company [36].

The intertwining of work and private relationships in a family business is aptly illustrated by the following picture.

Family businesses have family members as employees, but they can have non-family members. This will also be reflected in managerial functions. A family has its own goals, and a business has its goals as well. Sometimes it is a problem that the goals overlap together [37].

The leading role in the management of a family business is held by the business owner or the founder of the business. He tries to manage events in the family business in such a way that the employees are loyal to the company's goals and fulfill the goals. According to many authors, the overlap of ownership and managerial positions leads the enterprise to such interests as long-term survival and the search for long-term results. Loyalty to the company increases when employees feel like family members or do not feel as if they are "strangers" from management [38].

It is characteristic of family businesses that they tend to be based on a spiral of independent ties that starts at the bottom organizational layer of the company and continues to its very top. This spiral can be replaced over time by a certain type of employment in a family business, while this fact has a direct impact on the functionality of both the family and the business [39] (Fig. 1).

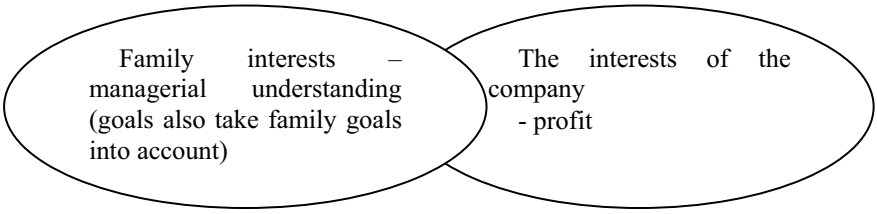


Fig. 1 Family business—interests, relationships, and management goals. *Source* [12]

3.2 Legislation in Slovakia on Family Business

From July 1, 2023, Act No. 112/2018 Coll. on the social economy and social enterprises and the amendment of some laws, as amended, on the issue of family business in the Slovak Republic [40]. A family business and its basic defining features are defined, while a family business must be an entrepreneur according to the provisions of §2 paragraph 2 of the Commercial Code:

(a) a person registered in the commercial register;
(b) a person who does business on the basis of a trade license;
(c) a person who does business on the basis of a license other than a trade license according to special regulations;
(d) a natural person who carries out agricultural production and is registered in accordance with a special regulation [41].

The range of defined persons is further narrowed down to selected legal forms, which include business company, cooperative and natural person—entrepreneur. This postulates the fact that a family business cannot be an entity that was not primarily established for the purpose of doing business, or that would perform an economic activity that does not have the nature of business. A new independent legal form is not created for family businesses, but defining characteristics of a family business are established for subjects of existing legal forms. The second of the basic defining characteristics of a family business is the existence of family ties in a family business.

3.3 The Family Business Model and the Czech Republic

This basic definition is inspired by several views at the level of the European Union states, while the proposed provision is closest to the Czech definition of a family business, as it was adopted by Resolution of the Government of the Czech Republic dated May 13, 2019, no. 330 on the definition of a family business in the Czech Republic. Its essence is:

a. majority exercise of voting rights in favor of members of one family,
b. participation in the management of the company through the person of the statutory body as a family member,
c. majority economic benefit of members of one family [42].

For the purposes of proving family ties, terms such as joint family or member of a joint family are used. Joint family members are defined as: spouses, relatives in the direct line, siblings and other persons related to each other up to the fourth degree and the spouses of these persons. The conditions under which development capital can enter a family business in the form of equity are determined, and it introduces a legal fiction where, with changed internal conditions, the business continues to meet the basic defining characteristics of a family business. The aim of such an adjustment

is to enable equity financing in addition to own and bank (or other debt) financing. Furthermore, it was determined that a registered family business is a family business that has been registered in the register of family businesses, and a registered family business is a family business that has gone through the registration process and has been granted the status of a registered family business. A family business that carries out agricultural activities is a family farm.

A characteristic feature of a family business is its Board as a collective body, whose internal organization and functioning are regulated by the Statute of the Board of a Family Business. The statute of the Family Business Council is approved by a business company, a cooperative or a natural person—an entrepreneur. The board of the family business mainly discusses:

(a) long-term strategic direction of the family business;
(b) family policy focused on the family business and the alignment of the goals of the family business and the goals of the family;
(c) relations between the family and the family business, the rights and obligations of the members of the joint family in relation to the family business, the needs and requirements of the members of the joint family;
(d) conditions for the admission of members of the joint family to the family business or the departure of members of the joint family from the family business;
(e) succession and preparation of the next generation to take over the family business, generational exchange of the statutory body or members of the statutory body and transfer of ownership or voting rights;
(f) information related to the family business provided to members of the board of the family business [43].

The board of a family business has at least three members. Most board members of a family business are members of a joint family. The board of a family business can reach a decision if most of all members of the board of the family business are present and more than 50% of the members of the board of the family business are members of the joint family [44]. The board of the family business adopts decisions by a majority of the votes of the members of the board of the family business present. Each member of the board of the family business has one vote. The statute of the board of the family business can determine when a higher number of votes of the members of the board of the family business is needed to decide.

4 Perspective of Family Businesses with Quality Management

4.1 Family Business and Employee Management

The owner must delegate authority in his family business. The introduction of management systems will subsequently increase the responsibility of employees. Employees will need more powers to do their jobs. The role of family businesses after they have delegated authority is to guide such managers who will act as their representatives [45].

It is also important to search for and employ new employees from an external environment. One of the advantages of well-run and managed family businesses is a group of young and promising employees. This group has two essential functions:

(1) peers of the owners' children, who compete with them for recognition and thereby stimulate their development;
(2) a new generation entering managerial positions from the ranks of external potential employees.

4.2 Family Business and Marketing Management

Product development and innovation in family businesses are undergoing significant changes due to new technologies. Social media brings changes in relationships with customers and potential customers. Also, the new thinking of customers and the influence of wide-spectrum information bring new wishes and wishes of customers.

Businesses, not only family ones, are having discussions on how to impress the customer, as it is increasingly difficult because customers are affected by the constant development of products. Another topic in marketing is how to sell, whether in brick-and-mortar stores or via e-shops. These controversies are a challenge for the future. Family businesses have one significant advantage over non-family businesses, namely that they have many years of continuous product development, innovation processes and stability on the market [43].

Some authors recommends adopting globalization processes in family businesses, but with an emphasis on the tradition of long-standing business. The author belongs to a family business that has been on the market since 1748 and the family business has gone through many social and political events [46–48].

All in all, we can conclude that a business needs quality management and leadership to ensure the achievement of business goals to prosper and make a profit. It also needs at least a basic marketing strategy and the use of marketing communication mix and marketing mix tools.

The public knows family businesses and their products by their trade name. We have already explained the definition of a business name in the first chapter. But let's

get back to product promotion management through the business name and form of the business.

Owners or managers add to the product the so-called added value, which can be:

1. tradition that constantly brings product improvement and higher product quality;
2. know-how of product production, tradition in product production;
3. certainty of a product complaint;
4. management of product references through family members (for example advertising Rauch juices/Austria or Monini olive oil/Italy) [28].

A family business manages its publicity in order to achieve the greatest possible sale of its products or services. Among the most used management signs, we can mention the following:

1. family business promotion management is also a business name, which is the name or name and surname of the founder of the business, for example, Deichmann, Raymond Weil, Dr. Oetker, Monini, Ford, Versace, L'oreal, Levi's, Karl Lagerfeld, Tissot, Breitling.
2. To manage the creation of a business name, the founder can also use an abbreviation of his first and last name, for example Hanwag-Joseph/Hans Wagner, Haribo—Hans Riegel from Bonn.
3. The packaging of the product has a protective function for the product but also an informational and marketing nature. The following information is placed managerially on the product packaging:
   (a) handwritten signature of the founder of the family business (for example, Monini, Dr. Oetker, Wiliam Grant and Sons;
   (b) information from which country the family business or family is from (for example, Made in Germany, Made in Austria), this information is now very rare, as most family businesses move their production outside of Europe;
   (c) the year of establishment of the family business is stated mostly in the native language of the founder of the family business (e.g., seit/since 1820), the older the date of establishment, the higher the quality and expertise and know-how of the product and its management;
   (d) photo of the founder and family members;
   (e) signature of the founder of the family business (William Grant);
   (f) logo of a family business with a long tradition [49].

5 Applying Quality Management to Improve the Functioning of the Family Business

5.1 Effective Management for the Development of Family Business

Mura and Stehlíková notes that a constant problem of small and medium-sized enterprises, and especially family enterprises, is managing all the activities of the manager "on his own" or under the direction of the family [50]. When starting a business, the wife's help is welcome, even necessary. The owner must delegate authority. The introduction of management systems will subsequently increase the responsibility of employees. Employees will need more power to do their jobs. The role of family businesses after they have delegated authority is to guide such managers who will act as their successors [51]. The whole family is involved in the business process also to realize the economy of individual management activities. Therefore, family members usually take care of all activities themselves or try to hire other family members for managerial activities.

When dividing managerial activities in a family business, for example, management decisions can be made as follows:

(a) the wife works in accounting or marketing,
(b) children to various managerial activities,
(c) one of the children is being prepared for the highest managerial position and later to take over the management of the family business.

For the family business to avoid stagnation, a formal management system must be introduced in the company. Such systems reward, evaluate and inform employees. Without these systems, the manager is not able to manage the company.

An example can be the family business of Emil Krajčík—101 Drogerie. Krajčíkovci belong to the constants of our ranking of family businesses. Emil Krajčík from Senice started his business in 1994. He started by selling cleaning and laundry products and other drugstore goods. He gradually managed to build one of the most famous drugstore chains in Slovakia. The first 101 Drogerie store was opened by Emil Krajčík in Nové Mesto nad Váhom. Today, the company has more than 200 establishments throughout Slovakia. In one year, they grew by 20 new stores. For several years, Emil Krajčík also dedicated his son Matej, a former soccer player who played for several seasons in Slavia Prague and in the highest league competition in Italy for the club Reggina Calcio, to the family business. The founder of 101 Drogerie is also developing the family agricultural business Emil Krajčík Agro, whose revenues reached almost two million euros last year and where his younger son Lukáš is also involved. His older son Matej should eventually take over the family business. Gradually, he gets to know the different departments of the company, but his father still has the main say in it [52].

5.2 Managing a Family Business, an Example Based on Analysis

Family businesses have a long-term, long-term advantage over other types of business, largely because of their long-term goals and plans. They are mostly stable in terms of ownership and assets. Without stability, they would lose their managerial priority [53]. A successful family business must be well managed. In a family business, quality management must ensure the following activities:

1. Planning,
2. Solving problems and conflicts,
3. Leadership and education of the next generation, exchange of generations.

The basis of good management of a family business is a functional leader [54]. It is also recommended to establish a family council, which will consult with the owner/founder on various decisions regarding the family business. In family businesses, it is customary for family members to be in management positions—top management. But it doesn't always have to be that way. If the family business is already established on the market, it can afford to appoint non-family members to the top management [55].

As an example, we will mention the Austrian family business Swarovski on July 4, 2022, Alexis Nasard became the new CEO of Swarovski, one of the top 30 luxury brands in the world and one of the largest family companies in the German-speaking region [35]. He is the first director of the 127-year-old luxury company who does not come from one of the founding families. As the new CEO, Nasard will also take over the management of the home office in Wattens, Tyrol. For Swarovski, this is another milestone in the management of the transition from a family-run company to a family-owned company. In November 2022, Swarovski introduced its new Board of Directors, which for the first time has a majority of independent members. The Swarovski family will continue to actively shape the legacy of company founder Daniel Swarovski in the role of owners. In addition, the fifth generation, Markus Langes-Swarovski, Robert Buchbauer and Mathias Margreiter, have three members on the board of Swarovski.

Managerial mistakes in family businesses

The most common management error in family businesses occurs during the change of generations. Generational change means that two generations alternate—junior and senior—and the change affects both at the same time. The risk lies precisely in the clash of two generations. Founders or owners often see themselves as irreplaceable and don't want to leave their position, and the next generation often wants to do things differently [56]. Mutual trust is therefore of the utmost importance, especially when handing over a family business. Another risk lies in the management of the timing of the generation change. Delaying or ignoring a basic succession plan causes problems.

There are two extremes:

1. the family business is handed over to the successor too early and the successor enters the business unprepared, or
2. the senior does not care at all about his successor and his education is neglected.

Both practices are equally harmful to the family business. Well-prepared succession planning therefore increases the probability of successfully handing over the family business to the next generation.

According to Zehrer, generational change does not happen overnight, it should be seen as a managerial systematic process that begins as a gradual development and requires detailed planning [57]. When changing generations in a family business, it is not only important to consider the tax, corporate and financial aspects, but also the psychological and emotional aspects. The generational change has a very high emotional value because it touches on the basic questions of the business, but also the personal existence of the follower [58].

6 Conclusion

6.1 Synopsis

Listed family business

A business that meets the conditions defined above can apply for inclusion in the register of family businesses. For this purpose, the Ministry of Labour, Social Affairs and Family (hereinafter referred to as "the Ministry") will issue a form. The request is assessed by the Ministry. A business that will be included in the register will be able to use the designation "family business" or the abbreviation "r. p."

Registered family business

In addition to a registered family business, the draft law also distinguishes a registered family business with the abbreviation r. r. Mr. To obtain the status of a registered family business, additional legal conditions must be met compared to a registered family business [59]. A registered family business must actually carry out an economic activity (only a formal entry in the relevant register is not enough), it must have its registered office in the territory of the Slovak Republic or another EU member state, it must be of good character (as well as its statutory body), it must not have committed the prohibition of illegal employment in period of three years prior to filing the application for registration, is not in bankruptcy, restructuring, liquidation and did not have the status of a registered family business revoked in the period of three years prior to filing the application for registration or was not legally decided not to grant the status of a registered business in the period of six months prior to filing the application [60].

The application form is also determined by the ministry, which also assesses the application together with the attachments and verifies the fulfillment of the conditions and issues a certificate granting the status of a registered family business.

The specifics of a registered family business should be the obligation to use at least 15% of the profit after tax to strengthen its internal and external relations within a period of up to one year from the date of approval of the regular financial statements. Specifically, it can be the use of resources, e.g., for the education of family members, pension provision of family members, recreational stays of family members and employees, etc. or also to add to a special fund established for this purpose. The percentage parts of the profit intended for this purpose should be defined in the basic document, which is submitted to the Ministry as an attachment to the application for registration. The proposed framework with its theoretical foundations in constructivist epistemology may be a starting point for developing enhanced models and improved approaches to overcome the limitations of traditional analytic-reductionist logic.

6.2 Further Research

The main problem of family businesses is the long-term issue of management and succession management. If family businesses ignore or neglect this area of development, the chances of premature termination of the business increase sharply. The company must follow this process long-term preparation, from the decision on the successor, through gradual passing on experience to gradually taking over responsibility. Or the management of a family business must think about management from an external environment.

This situation is a good illustration of the problem when the expectations of family businesses differ significantly from the reality that occurs. In other words, family businesses don't expect succession problems until they realize they started preparing too late. Another key factor that can have a significant impact on the future of family business is the introduction of digitization. Businesses around the world expect their digitization rate to increase from 33% in 2015–72% by 2020. The highest level of digitization is expected in the preparation and use of digital business plans and a portfolio of products and services. A similar growth in the penetration of digital technologies is also expected in customer access, marketing, and sales channels, and in the areas of horizontal and vertical chains.

In this, we see calls for a better direction of the management of family businesses, that is, to choose the management of the company from its own human resources or to reach out to external human resources.

Currently, Slovakia must focus mainly on the following areas of development education:

- Introduce education aimed at supporting family businesses, especially in the environment of universities, for example in the form of an independent one subject Family business;
- Initiate long-term cooperation between academic workplaces, research agencies and development centers;
- Promote and increase the level of cooperation of universities and colleges with by their students and their involvement in scientific research activities;
- Conduct training courses and prepare qualification materials, for example, through the simulation of business processes and situations for which potential entrepreneurs should be prepared;
- Prepare a manual with procedures for taking over the company by the following by generation;
- Regularly publish a professional magazine specialized in the field of family business and problems associated with it;
- Create a space for providing services to family startups businesses where they could meet with specialized consultants in individual areas of business—for example, accounting, succession, division of responsibilities in the family, development planning business;
- Establish an institution dedicated to the needs of family businesses and major the problems they have to face and the development of the best measures to support them;
- Promote the establishment of family businesses as a career option and form of self-realization;
- Motivate new generations to establish family businesses and develop incentive program for those who will have the courage to choose their own path.

References

1. Adamisin, P., Kotulic, R., Mura, L., Kravcakova Vozarova, I., Vavrek, R.: Managerial approaches of environmental projects: an empirical study. Pol. J. Manag. Stud. **17**(1), 27–38 (2018). https://doi.org/10.17512/pjms.2018.17.1.03
2. Elfimova, O.: Personality and charisma as prerequisites for a leading position in public administration. Springer Proc. Bus. Econ. 199–211 (2018). https://doi.org/10.1007/978-3-319-74216-8_21
3. Funta, R.: Economic and legal features of digital markets. Danube **10**(2), 173–183 (2019). https://doi.org/10.2478/danb-2019-0009
4. Gubíniová, K., Štarchoň, P., Vilčeková, L., Bartáková, G.P., Brtková, J.: Marketing communication and its role in the process of creating rational awareness of generation Z representatives. Stud. Syst., Decis. Control. **376**, 203–221 (2021). https://doi.org/10.1007/978-3-030-76632-0_6
5. Kaššaj, M.: The influence of jurisprudence on the formation of relations between the manager and the limited liability company. Juridical Trib. **13**(1), 43–62 (2023). https://doi.org/10.24818/TBJ/2023/13/1.04
6. Kajanová, J., Matúšová, S., Nováček, P.: Sustainable business in the European economic area. Juridical Trib. **12**(4), 495–508 (2022). https://doi.org/10.24818/tbj/2022/12/4.04

7. Srebalová, M., Mucha, B.: Nuclear waste potential and circular economy: case of selected European country. Stud. Syst., Decis. Control. **462**, 271–292 (2023). https://doi.org/10.1007/978-3-031-25695-0_13
8. Srpová, J., Řehoř, V.: Podnikání malé a střední firmy. Grada Publishing, Praha (2010)
9. Vilčeková, L., Mucha, B., Peráček, T. Strážovská, Ľ.: Selected issues of family business in selected countries with emphasis on the Slovak Republic. In: Proceedings of the 31st International Business Information Management Association Conference, IBIMA 2018: Innovation Management and Education Excellence through Vision 2020, pp. 2500–2509 (2018)
10. Kaššaj, M.: A critical analysis of the rights and obligations of the manager of a limited liability company: managerial legislative basis. LAWS. **12**(3), 56, 1–21 (2023). https://doi.org/10.3390/laws12030056
11. Peráček, T.: Flexibility of creating and changing employment in the options of the Slovak Labor Code. Probl. Perspect. Manag. **19**(3), 373–382 (2021). https://doi.org/10.21511/ppm.19(3).2021.30
12. Strážovská, Ľ.: Marketing malého, stredného a rodinného podnikania. Sprint2, Bratislava (2019)
13. Šubová, N., Mura, L., Buleca, J.: Determinants of household financial vulnerability: evidence from selected eu countries. E a M: Ekon. Manag. **24**(3), 186–207 (2021). https://doi.org/10.15240/TUL/001/2021-3-011
14. Palatický, Š, Keller, K., Mußmann, A.: European digital strategy and its impact on the conclusion of selected types of business contracts. Stud. Syst., Decis. Control. **462**, 443–468 (2023). https://doi.org/10.1007/978-3-031-25695-0_20
15. Mucha, B., Brestovanska, P., Kajanova, J.: Selected ways of acquiring securities in the conditions of the Slovak Republic. Acta Univ. Agric. Silv. Ulturae Mendel. Brun. **66**(6), 1589–1599 (2018). https://doi.org/10.11118/actaun201866061589
16. Vilcekova, L., Strazovska, L.: Selected problems of family business: a case study from Slovakia. Acta Polytech. Hung. **17**(7), 145–162 (2020). https://doi.org/10.12700/APH.17.7.2020.7.8
17. Khorsand, P.N.N.-H.: Home office—benefit for employer or employee? Stud. Syst., Decis. Control. **462**, 349–373 (2023). https://doi.org/10.1007/978-3-031-25695-0_16
18. Kita, P., Maciejewski, G., Čvirik, M., Mazalánová, V.K.: New factors of consumer behaviour in the context of business models used in retailing during the COVID-19 era. Forum Sci. Oecon. **10**(3), 75–92 (2022). https://doi.org/10.23762/FSO_VOL10_NO3_4
19. Kita, J., Máziková, K., Grossmanová, M., Kita, P.: Trade practices of retail chains as far as the transaction cost analysis in the relationships manufacturer—retailer are concerned in the milk industry. Agric. Econ. (Czech Repub.) **58**(6), 264–274 (2012). https://doi.org/10.17221/61/2011-agricecon
20. Gregušová, D., Halásová, Z.: EIDAS regulation and its impact on national legislation: the case of the Slovak Republic. Adm. Sci. **12**(4), 187 (2022). https://doi.org/10.3390/admsci12040187
21. Nováčková, D., Vnuková, J.: Competition issues including in the international agreements of the European union. Juridical Trib. **11**(2), 234–250 (2021). https://doi.org/10.24818/TBJ/2021/11/2.06
22. Peráček, T.: Impact of European legislation and case-law on elimination of discrimination in employment relations in EU. Online J. Model. New Eur. **36**, 65–82 (2021). https://doi.org/10.24193/OJMNE.2021.36.04
23. Skrabka, J.: The moratorium on loan repayments during the covid-19 pandemic in Europe: a comparative analysis of loan moratoria in selected European countries. Juridical Trib. **11**(SI), 291–301 (2021). https://doi.org/10.24818/TBJ/2021/11/SP/02
24. Dudic, B., Dudic, Z., Pejanovic, R., Skataric, G., Saxunova, D.: The rural policy of Slovakia after joining the EU. Agric. For. **66**(3), 33–51 (2020). https://doi.org/10.17707/AgricultForest.66.3.04
25. Gogová, A.: Case study of the knowledge management process in selected department of state administration in lovakia. Stud. Syst., Decis. Control. **420**, 533–545 (2022). https://doi.org/10.1007/978-3-030-95813-8_21

26. Hajduova, Z., Coronicova Hurajova, J., Bruothova, J.: Determinants of innovativeness of Slovak SMEs. Probl. Perspect. Manag. **19**(1):198–208 (2021). https://doi.org/10.21511/ppm.19(1).2021.17
27. Jančíková, E., Pásztorová, J.: Promoting eu values in international agreements. Juridical Trib. **11**(2), 203–218 (2021). https://doi.org/10.24818/TBJ/2021/11/2.04
28. Králiková, K., Funta, R.: Obligation of the European commission to review national civil court judgements? Juridical Trib. **12**(2), 215–226. https://doi.org/10.24818/TBJ/2022/12/2.04
29. Ispas, G.L.: Impact of the covid-19 on the migration in the European Union. Juridical Trib. **11**(1), 30–41 (2021)
30. Brusatti, A.: Familienunternehmen. ÖGU, Wien (2017)
31. Aksamovic, D., Simunovic, L.: The EU scheme for the state aid rules in the air transport sector during the Covid-19 crisis. Juridical Trib. **12**(1), 51–67 (2022)
32. Brestovanska, P., Kajanova, J.: Simple company on shares as startup support tool. Acta Univ. Agric. Silv. Ulturae Mendel. Brun. **66**(6), 1601–1611 (2018). https://doi.org/10.11118/actaun201866061601
33. Fedushko, S., Trach, O., Syerov, Y., Kryvinska, N., Calhoun, J.R.: Web project development: emergency management. J. Web Eng. **21**, 2257–2286 (2022). https://doi.org/10.13052/jwe1540-9589.2182
34. Čajková, A., Šindleryová, I.B., Garaj, M.: The covid-19 pandemic and budget shortfalls in the local governments in Slovakia. Sci. Pap. Univ. Pardubice, Ser. D: Fac. Econ. Adm. **29**(1), 1243 (2021). https://doi.org/10.46585/sp290112436
35. Mimoso, M.J., de Azevedo, L.C.: The need for a harmonious interpretation of the rules applicable to international contracts. Juridical Trib. **12**(1), 68–79 (2022). https://doi.org/10.24818/TBJ/2022/12/1.05
36. Groza, A.: The principle of mutual recognition: from the internal market to the European area of freedom, security and justice. Juridical Trib. **12**(1), 89–104 (2022)
37. Tashev, A., Takenova, Z., Arshidinova, M.: Algorithms for solving problems of resources allocation in the management of business processes in educational organizations. Int. J. Mod. Educ. Comput. Sci. (IJMECS) **15**(5), 14–27 (2023). https://doi.org/10.5815/ijmecs.2023.05.02
38. Funta, R.: Relationships between platforms and retailers (on the example of Amazon). AUC IURIDICA **69**(2), 83–94 (2023). https://doi.org/10.14712/23366478.2023.16
39. Peráček, T.: A few remarks on the (im)perfection of the term securities: a theoretical study. Juridical Tribune—Tribuna Juridica **11**(2), 135–149 (2021). https://doi.org/10.24818/TBJ/2021/11/2.01
40. National Council of the Slovak Republic.: Act No. 112/2018 Coll. on the social economy and social enterprises and on the amendment of certain laws as amended (2018). Available at: https://www.slov-lex.sk/pravne-predpisy/SK/ZZ/2018/112/20230701
41. Federal Assembly of the Czech and Slovak Federal Republic. Act no. 513/1991 Coll. Commercial Code as Amended. Available at: https://www.slov-lex.sk/vyhladavanie-pravnych-predpisov?text=513%2F1991. (1991)
42. Pavelek, O., Zajíčková, D.: Personal data protection in the decision-making of the CJEU before and after the Lisbon treaty. TalTech J. Eur. Stud. **11**(2), 167–188 (2021). https://doi.org/10.2478/bjes-2021-0020
43. Von Boch, W.: Globalisieren mit Tradition. Orell Fuessli Verlag AG, Zurich (2007)
44. Matúšová, S., Nováček, P.: New generation of investment agreements in the regime of the European Union. Juridical Trib. **12**(1), 21–34 (2022). https://doi.org/10.24818/TBJ/2022/12/1.02
45. Masár, D., Jankelová, N.: Knowledge management as a tool for increasing the efficiency of municipality management in Slovakia. Knowl. Manag. Res. Pract. **21**(2), 292–302 (2023). https://doi.org/10.1080/14778238.2021.1895686
46. Abrhám, J., Čajka, P.: Regional aspects of V4 countries' economic development over a membership period of 15 years in the European union. Slovak J. Polit. Sci. **19**(1), 89–105 (2019). https://doi.org/10.34135/sjps.190105

47. Stoličná, Z., Klapáčová, L.: The role of household consumption in a very small, very open economy. In: Demir, E., Bilgin, M.H., Danis, H., D'Ascenzo, F. (eds) Eurasian Business and Economics Perspectives. EBES 2022. Eurasian Studies in Business and Economics, vol 26. Springer, Cham. (2023). https://doi.org/10.1007/978-3-031-30061-5_28
48. Kryvinska, N., Strauss, C., Zinterhof, P.: Next generation service delivery network as enabler of applicable intelligence in decision and management support systems. Chapter 18. In: Besis, N., Xhafa, F. (eds.) Next Generation Data Technologies for Collective Computational Intelligence. Studies in Computational Intelligence, pp. 473–502 . Springer, Berlin Heidelberg (2011)
49. Majtán, M. et al.: Manažment. Sprint2, Bratislava (2012)
50. Mura, L., Stehlikova, B.: Innovative approaches: using DEMATEL method in the research of SMEs operating in tourism sector. In: Valeri, M. (ed) Family Businesses in Tourism and Hospitality. Tourism, Hospitality & Event Management. Springer, Cham (2023). https://doi.org/10.1007/978-3-031-28053-5_10
51. Mura, L., Zsigmond, T., Bakó, F., Marcell, K.: New organizational environment types based on Garvin and Quinn—the case of Slovakian small and medium enterprises. TEM J. **12**(2), 691–699 (2023). https://doi.org/10.18421/TEM122-12
52. Kajanova, J., Novacek, P.: Environmental crimes and bentonite mining and processing companies in Slovak Republic. TalTech J. Eur. Stud. **12**(2), 43–63 (2022). https://doi.org/10.2478/bjes-2022-0011
53. Martel, J.: Rodinné firmy na rozcestí. Grada Publishing, Praha (2017)
54. Buttler, D., Funta, R.: The digital economy and legal challenges. Intereulaweast. **10**(1), 145–160 (2023). https://doi.org/10.22598/iele.2023.10.1.8
55. Olšavský, F., Štarchoň, P., Mitková, Ľ, Dudić, B.: Dynamics of the Slovak consumer behavior in the context of ethnocentrism: managerial implications. Agric. For. **68**(3), 7–21 (2022). https://doi.org/10.17707/AgricultForest.68.3.01
56. Novackova, D.: The common European investment policy and its perspectives in the context of the achmea case law. Tal Tech J. Eur. Stud. **11**(1), 153–169 (2012). https://doi.org/10.2478/bjes-2021-0010
57. Zehrer, A.: MCI Management Center. Innsbruck (2023)
58. Zakharchenko, A., Fedushko, S., Syerov, Y., Trach, O.: When fact-checking and 'bbc standards' are helpless: 'fake newsworthy event' manipulation and the reaction of the 'high-quality media' on it. Sustainability **13**(2), 1–13, 573 (2021). https://doi.org/10.3390/su13020573
59. Paškrtová, L., Nováčková, D., Vnuková, J.: Cross-border provision of services: case study in the Slovak Republic. Adm. Sci. **13**(2), 54 (2023). https://doi.org/10.3390/admsci13020054
60. Vnuková, J.: Relationship between EU law and national law in the context of case law of judicial bodies. Juridical Trib. **12**(4), 538–551 (2022). https://doi.org/10.24818/tbj/2022/12/4.07

Network Approach to Linguistic Pattern Analysis for User Gender Identification of Social Internet Services

Solomiia Fedushko

Abstract Gender is a determinant of online social behavior, and it is important to understand gender dynamics in online spaces. This study examines gender identification as a conceptual framework for analyzing the content of social internet services and explores the complex dynamics of social internet services, focusing on the significant influence of gender identification on digital interactions. By integrating gender analysis, this research aims to comprehensively understand user behavior, communication patterns, and intent in social internet services. The research provides insights into the role of gender in online discourse, contributes to the understanding of how spatial cues and gender dynamics shape communication in social internet services and provides insights into online interaction patterns. This paper focuses on analyzing gendered communication patterns through the lens of network models and descriptive statistics. The study examines two representations of network models—activity-arc and activity-vertex—and uses Python libraries for data analysis. The data set, divided into control and experimental groups, is numerically scaled, and descriptive statistics reveal remarkable insights. Examination of linguistic characteristics reveals distinct differences between control groups F and M of users of social internet services. The study applies a matrix subtraction technique and uses network models to analyze communication characteristics across gender groups of users of social internet services. The results indicate differences in linguistic patterns between male and female groups of users of social internet services and represent visualizations and descriptive statistics.

Keywords Gender identification · Online communication · Network models · Linguistic patterns · User behavior · Social internet services · Digital interaction

S. Fedushko (✉)
Lviv Polytechnic National University, Lviv 79000, Ukraine
e-mail: solomiia.s.fedushko@lpnu.ua

Comenius University in Bratislava, 820 05 Bratislava, Slovakia

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2024

P. Štarchoň et al. (eds.), *Data-Centric Business and Applications*, Lecture Notes on Data Engineering and Communications Technologies 213,
https://doi.org/10.1007/978-3-031-62213-7_7

1 Introduction

In the ever-evolving realm of social internet services, a wide variety of viewpoints and assessments converge to form an intricate web of dialogue, engagement, and correspondence. It is critical to acknowledge the complexities of these digital environments, one of which is the significant impact of gender identification on the content produced in social internet services. It is imperative to incorporate gender analysis into the study of social internet services content to gain a holistic understanding of user behavior, communication trends, and the underlying intricacies of these communities.

The advent of the digital age has bestowed upon individuals unparalleled prospects to express their viewpoints, participate in varied discussions, and establish connections with like-minded individuals. Yet the influence of gender on content production and consumption remains an important but understudied topic. Understanding how gender identification is incorporated into content analysis provides valuable insights into the various sociocultural, linguistic, and behavioral factors that influence online interactions.

This research aims to investigate whether gender identification of the users of social internet services serve as a conceptual framework for analyzing the content of social internet services. Using sophisticated content analysis techniques, we aim to uncover the subtleties, linguistic irregularities, and communication trends that are influenced by users' gender identities. The study of gendered communication dynamics in the digital realm is pertinent in light of the current state of digital communication.

In addition to its academic significance, understanding gender differences in social media use is essential to understanding the intricate workings of online social interactions. This knowledge has the potential to shape policy decisions and inform platform design. Determine the effect that gender biases have on online players, prior research has examined player interactions and character development. By analyzing the participation of men and women in online activism and social movements, we aim to understand the extent to which gender biases influence discourse and perceptions. Our ultimate goal is to confront and correct these biases.

The analysis of online dangers and difficulties faced by individuals, including but not limited to cyberbullying, harassment, and privacy violations, is a focal point.

Gender-identifying online communication offers numerous benefits to consumers, such as personalized recommendations, gender-differentiated interaction, targeted advertising, and promoting principles of equality and inclusiveness. The utilization of gender data must adhere to ethical principles that safeguard the privacy of users and acknowledge the diverse array of gender identities and expressions.

Profile data, textual content analysis, social media analysis, machine learning, visual content analysis, and surveys are all viable approaches to determining gender. However, no method can guarantee complete accuracy, so ethical and privacy concerns must take precedence.

Software-dependent gender identification is critical in many areas, including advertising targeting and security. However, it is imperative to thoroughly examine the ethical concerns that arise from the collection and use of gender data, with an emphasis on complying with legal requirements and maintaining transparency in the operation of the tool.

2 Related Work

In the dynamic realm of Internet communication, it is of the utmost importance to comprehend the intricate impact that gender has on digital interactions. This section provides an overview of ongoing research that seeks to explore the impact of gender on communication and interaction in the digital environment. They highlight specific trends in the field, addressing issues such as gender differentiation in social media use, gender roles in online gaming, gender differences in digital activism, the interplay of the Internet and gender in business, and the crucial aspect of gender safety online.

This study provides insights into the legal and policy aspects of online gender-based violence, setting the foundation for understanding the challenges associated with online communication and gender issues.

Barlińska et al. [1] investigated cyberbullying among adolescent bystanders, considering the role of communication medium, the form of violence, and empathy. This work contributes to understanding the dynamics of cyberbullying and its impact on adolescents, particularly emphasizing the role of communication in online aggression.

Chai et al. [2] explored factors influencing bloggers' knowledge sharing, investigating these dynamics across genders. The findings shed light on how gender plays a role in knowledge sharing within online platforms, contributing to the broader understanding of online collaboration.

Iosub et al. [3] delved into emotions in online collaboration, examining the intersections of gender, status, and communication. This research provides valuable insights into the emotional aspects of online interactions, addressing the role of gender in shaping communication dynamics.

Crocco et al. [4] investigated gender equity in social studies research on technology, focusing on the twenty-first century. By exploring the gender gap in social studies research, this study contributes to understanding gender disparities in the technological landscape.

Guiller and Durndell [5] explored gender interactions in educational online discussion groups. This work offers insights into how gender influences online educational discourse, contributing to the broader understanding of gender dynamics in online learning environments.

Hartsell [6] conducted a descriptive analysis of gender and online communication, providing insights into online communication patterns across genders. This research contributes to understanding the role of gender in shaping online discourse.

Kapidzic and Herring [7] revisited gender, communication, and self-presentation in teen chatrooms. This study sheds light on changes in patterns over time, contributing to a nuanced understanding of gender dynamics in teen online communication.

Li [8] conducted a comprehensive review of gender and computer-mediated communication (CMC), mainly focusing on conflict and harassment. This review provides a foundational understanding of gender-related challenges in online communication.

Li et al. [9] investigated the roles of emotional disclosures and gender cues in communicating social support online. This research contributes to understanding how gender influences the provision of social support in online environments.

Manago et al. [10] explored self-presentation and gender on MySpace. The study contributes to understanding how individuals present themselves online, focusing on the role of gender in shaping online identity.

Mansell and Raboy [11] comprehensively examined global media and communication policy. This handbook offers insights into the complex landscape of global media and communication, contributing to a broader understanding of policy implications.

Marshall [12] discussed gender in online communication within the broader context of new literacies. This chapter provides insights into the intersection of gender and new literacies, contributing to the evolving field of digital communication.

Owen et al. [13] investigated the effects of gender and preparation on the quality of communication in Internet support groups. The study contributes to understanding how gender and preparation influence communication dynamics in online support groups.

Pavan [14] focused on internet intermediaries and online gender-based violence. This research contributes to understanding the role of internet intermediaries in addressing and preventing online gender-based violence.

Prinsen et al. [15] explored gender-related differences in computer-mediated communication and computer-supported collaborative learning. The study contributes to understanding how gender influences collaborative learning in online environments.

Royal [16] conducted a meta-analysis of journal articles intersecting issues of the Internet and gender. This meta-analysis provides a comprehensive overview of research on the intersection of internet use and gender, contributing to the broader understanding of gender dynamics in online spaces.

Buchmüller et al. [17] applied a participatory design process to bridge the gender and generation gap in information and communication technology (ICT). This study contributes to understanding how participatory design processes address gender and generation gaps in ICT.

Mishra et al. [18] proposed an automated model for sentimental analysis using an extended short-term memory-based deep learning model. This research contributes to sentiment analysis, providing an automated approach with deep learning techniques.

Savicki and Kelley [19] examined gender and group composition in computer-mediated communication. The study provides insights into how gender and group composition influence communication dynamics in online settings.

Korobiichuk et al. [20] explored methods of determining information support for web community users' personal data verification systems. This study contributes to understanding information support systems for verifying users' personal data in web communities.

Sethna et al. [21] investigated the influence of user-generated content on online shopping, specifically examining the impact of gender on purchase behavior, trust, and intention to purchase. This study examines how user-generated content influences online consumer behavior, focusing on gender differences.

Juyal et al. [22] proposed an enhanced approach to recommend data structures and algorithm problems using content-based filtering. This research contributes to recommendation systems, providing an advanced method for suggesting relevant problems based on individual preferences.

Abafogi [23] focused on boosting Afaan Oromo Named Entity Recognition with multiple methods. This study contributes to natural language processing, showcasing the application of various methods to enhance the recognition of named entities in the Afaan Oromo language.

Sichler and Prommer [24] explored gender differences within the German-language Wikipedia. This study provides insights into gender participation and contributions to German Wikipedia.

Kavoura and Stavrianea [25] investigated the characteristics and gender differences of online travel community members in social media concerning following and belonging. The research contributes to understanding the dynamics of online travel communities, particularly considering gender-related aspects.

Asmus et al. [26] analyzed linguistic features of gender differences in blog communication. This study offers insights into how language choices vary between genders in the context of blogging, contributing to the understanding of gendered communication patterns.

Guiller and Durndell [27] examined students' linguistic behavior in online discussion groups, focusing on the influence of gender. The findings contribute to understanding how students express themselves linguistically in online educational settings, considering gender dynamics.

Thelwall et al. [28] applied data mining techniques to analyze emotion in social network communication, exploring gender differences on MySpace. This research contributes to understanding the role of emotions and gender in shaping online communication.

Zhang and Fu [29] investigated privacy management and self-disclosure on social network sites, exploring the moderating effects of stress and gender. This study contributes to understanding how individuals manage privacy and disclose information online, considering the influence of gender.

Rollero et al. [30] explored whether men post and women view in the context of online social activity. This research provides insights into gender differences in online social behaviors, shedding light on the roles of men and women in online communication.

Chai et al. [31] investigated the effect of communication on college students' online decisions, focusing on gender differences. The study contributes to understanding how gender influences decision-making processes in online environments, specifically in college students' context.

Suzuki [32] analyzed gender-linked differences in informal arguments within an online newspaper. This research provides insights into how gender shapes informal argumentation in online journalistic contexts, contributing to understanding gender dynamics in online discourse.

Hargittai and Shaw [33] explored the skills gap in contributions to Wikipedia, considering internet know-how and gender. The study contributes to understanding how internet skills and gender intersect in differentiated contributions to collaborative online platforms, mainly Wikipedia.

Sultan et al. [34] developed a machine-learning model for cyberbullying detection from social-media images or screenshots with optical character recognition. This study contributes to the field of cybersecurity, providing an automated approach to identifying instances of cyberbullying.

Saha and Kumar [35] focused on emoji prediction using emerging machine-learning classifiers for text-based communication. The study contributes to understanding the application of machine learning in predicting user expressions in online text communication, particularly in the context of emojis.

Teso et al. [36] applied text-mining techniques to analyze discourse in eWOM communications from a gender perspective. This research contributes to understanding how text mining unveil gender-related patterns in online communication, specifically in the context of electronic word-of-mouth.

Wu et al. [37] explored communication in virtual environments, investigating the influence of spatial cues and gender on verbal behavior. The study contributes to understanding how spatial cues and gender dynamics shape communication in virtual spaces, providing insights into online interaction patterns.

Zolduoarrati and Licorish [38] discussed the importance of promoting gender tolerance and inclusivity in software engineering communities. The work contributes to understanding the importance of fostering inclusivity and gender tolerance in social internet services related to software engineering.

These emerging trends underscore the growing importance of gender issues in online communication. The following sections examine methods for determining gender in online communication, the potential benefits of software-based gender identification, and the ethical considerations associated with using gender data.

3 Results

Identifying the gender of online users offers several advantages to consumers. Online services use gender information to provide customized recommendations, content, or features that cater to users' interests and needs. Some services modify their interaction and presentation of information to enhance a particular user's understanding and comfort based on their gender identification. Advertisers create more targeted and effective advertising campaigns and provide more relevant information to users by using gender data. Certain online platforms use gender data to promote greater equality and inclusion by ensuring equal access and representation of different gender groups in the digital environment. To create a more diverse online environment and accommodate users who wish to define their gender identity, online services must use appropriate gender references and other relevant parameters. However, it is essential to adhere to ethical principles, protect user privacy, and recognize the wide range of gender identities and expressions while using gender data.

Determining the gender of users of social internet services can be done using various methods, and many of them reflect a wide range of approaches and accuracy. Below are some of the main methods for determining gender:

- Profile data. Many users indicate their gender in their profile. However, this information may be incomplete or inaccurate; users may provide false information or leave this field blank.
- Analyzing textual content. Natural Language Processing techniques are used to analyze textual content generated by a user. Algorithms consider language usage, communication style, and the use of certain words and phrases to determine gender identity.
- Social media analysis. Incorporating data from social media sites such as Facebook, Reddit, X, or Instagram can help determine gender based on user information in their profiles, photos, statements, etc.
- Machine learning. The algorithms of machine learning are used to analyze a wide range of factors that indicate gender, such as language style, frequency of use of certain words, geographic data, etc.
- Network model. Utilizing a network model involves assessing the user's connections and interactions within a network. This method examines the relationships between users, considering patterns and associations that may reveal gender information. Network models can capture the social structure and connections, contributing to gender determination.
- Analysis of visual content. Gender determination also considers analyzing photos included in a user's profile. Facial and feature recognition algorithms highlight certain features that indicate gender identity.
- Surveys and questionnaires. Some services may use a direct question about gender identity in their surveys or questionnaires.

Network models are used for gender-identifying online communication of users of social internet services because they provide insights into social structure, pattern

recognition, community influence, contextual understanding, behavioral analysis, privacy considerations, adaptability to evolving identities, and enhanced accuracy. These models help understand relationships, patterns, and associations within social internet services, enabling a more comprehensive analysis of how gender identities are expressed and perceived. They also provide context for understanding user behavior of social internet services, allowing for the extraction of behavioral features indicative of the gender identity of users of social internet services. Network models also be complementary when integrated with other methods like textual analysis or visual content analysis, enhancing overall accuracy.

Network models are a very convenient tool for describing, analyzing, and optimizing projects, as they are a type of oriented (directed) graphs consisting of arcs and vertices. Sometimes, events that determine the start and end of individual activities play the role of graph vertices, and arcs, in this case, correspond to activities. Graphs of this type are called "activity-arc," and the corresponding network model is called the network model with activities on arrows (AOA) [39]. Most project management systems do not currently support this outdated model. It is possible that in a network model, the graph's vertices are activities, and the arcs reflect the correspondence between the end of one activity and the beginning of the next. Graphs of this type are called "activity-vertex," and the corresponding network model is called a network model with activities on nodes (AON) [40]. Microsoft Project implements this type of model. In the translation literature, activities are often called tasks (this is a more accurate translation of the term task). For the purposes of this methodological guide, to avoid misinterpretation of the Microsoft Project user interface, the term "task" will be used in part related to the direct work with this software product.

The following types of work are distinguished:

- simple
- event (work with zero duration, work—milestone)
- total (consisting of many works of any kind embedded in it).

This paper will consider two basic representations of network models: a network graph and a timeline. Let us take a closer look at them.

A network graph is a graphical representation of a network model's structure on a plane. We used the Python libraries pandas, numpy, matplotlib, and seaborn to conduct this study and uploaded the dataset [41] to the Jupyter Notebook analytics development and analysis environment (Fig. 1).

Categorized the data set into 3 categories and converted them to NumPy format:

- Control group (F, M).
- Experimental group (F1, M1).
- All observations.

Defined functions for numerical scaling (MinMaxScaler and Standardization).

The data was scaled using MinMaxScaler [42]. Converted the values of all observations to the interval [0; 1].

We found the descriptive statistics of the resulting set of numerical values (Fig. 2).

```
B [5]: data = pd.read_csv("D:/my_files/Research/Internet communication/forum-data-english.csv")
       data.head()
```

Out[5]:

	Participants	F1	M1	F	M
0	Apology	0.020	0.0015	0.0240	0.0114
1	Modal Constructions	0.030	0.0600	0.0239	0.0180
2	Mention of emotions and feelings	0.035	0.0250	0.0360	0.0230
3	Answer evasion	0.010	0.0290	0.0290	0.0060
4	Time links	0.003	0.0560	0.0074	0.0480

Fig. 1 Data loaded into the workspace

```
B [79]: num_data_scaled = min_max_scaler(num_data)

        scaled_num_data_df = pd.DataFrame(num_data_scaled, columns=["F1", "M1", "F", "M"])
        scaled_num_data_df.describe()
```

Out[79]:

	F1	M1	F	M
count	48.000000	48.000000	48.000000	48.000000
mean	0.325707	0.316120	0.341270	0.278568
std	0.284319	0.266695	0.272973	0.270732
min	0.000000	0.000000	0.000000	0.000000
25%	0.094378	0.063749	0.129356	0.081893
50%	0.231748	0.278983	0.260269	0.166515
75%	0.523022	0.500286	0.500681	0.422202
max	1.000000	1.000000	1.000000	1.000000

Fig. 2 Calculation of descriptive statistics

After analyzing the descriptive statistics, we made the following conclusions about the dataset [41]:

- The number of observations for each group is 48, which is expected.
- We notice that females (F and F1) tend to have higher mean values compared to male groups (M and M1).
- The standard deviation in the control group for both genders remains almost the same. However, in the experimental group, F1 has a slightly larger standard deviation than M1. This means that F1 values have a higher dispersion, while M1 values are closer to the statistical mean of all numerical values and slightly less distributed compared to F1.
- The minimum and maximum values are the same and are 0 and 1, respectively. It would be interesting to find out what factors these values correspond to.
- According to the percentiles, women in the control group have higher values than men. However, we do not observe such a big difference in the experimental group. For example, for the 25th and 75th percentiles, F1 has higher results, but for the 50th percentile, M1 is superior to F1. This is an indicator that M1 scores higher than F1 on some factors.
- Visualizing the data using box plots and swarm plots would be appropriate.

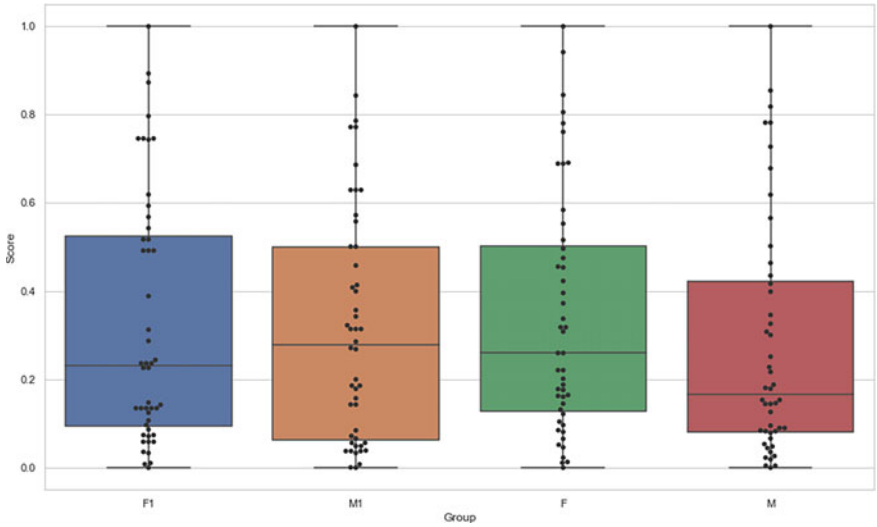


Fig. 3 Distribution of numerical values of different data groups of social internet services users

We visualized all the numerical values using a combination of box plots and swarm plots. The graph with the distribution of numerical values of all groups of users of social internet services is shown below (Fig. 3).

The following conclusions are currently available:

- It can be confirmed that F and F1 have slightly higher scores than M and M1.
- Although the difference between F1 and M1 is negligible, it was evident between the M and F groups.
- It is worth investigating the deviations and determining at what levels different linguistic factors exist for the groups analyzed.

Further work is needed to investigate the difference between the linguistic characteristics of groups F and M of users of social internet services. The following key characteristics should be highlighted for a better understanding of the process:

- F and M are the control groups.
- Find the difference between the values of F and M of users of social internet services.
- Accordingly, if the resulting value of this subtraction operation for a certain communication characteristic is negative, group M has a higher indicator, and group F has a lower indicator.
- Accordingly, the lower the value obtained, the higher the score for group M. And vice versa, the higher the value, the lower the score for group M than for group F.

The result of the calculations is the matrix shown in the graph below (Fig. 2). The data was "filtered" to certain thresholds to determine which indicators of one group differed most from those of the other and the most similar ones. It is important to

```
B [249]: final_cor_matrix_df[(final_cor_matrix_df.ge(-0.1)) & (final_cor_matrix_df.le(0.1))]
```

Out[249]:

Factors	Apology	Modal Constructions	Mention of emotions and feelings	Answer evasion	Time links	Affirmation	Order	Long words	Profanity	Adjective expressions without semantic meaning	...	Meaningless expressions	Clarificatior
Apology	NaN	NaN	0.055481	NaN	NaN	-0.046430	NaN	NaN	NaN	NaN	...	NaN	Na
Modal Constructions	NaN	NaN	0.053534	NaN	NaN	-0.048377	NaN	NaN	NaN	NaN	...	NaN	Na
Mention of emotions and feelings	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	-0.038490	NaN	...	NaN	Na
Answer evasion	NaN	NaN	NaN	NaN	NaN	0.050903	NaN	NaN	NaN	NaN	...	NaN	Na
Time links	-0.056564	NaN	NaN	0.041707	NaN	NaN	-0.012888	-0.014708	NaN	-0.021987	...	0.048986	Na
Affirmation	-0.000111	NaN	NaN	0.098160	NaN	NaN	0.043565	0.041745	NaN	0.034466	...	NaN	Na

Fig. 4 The matrix after subtraction of F and M

note that we worked with normalized numerical values that fall within the interval [0; 1]. The following thresholds were selected:

- value ≤ -0.8 is the lower threshold value for identifying those characteristics that have high values in group M but low values in group F
- value ≥ 0.8 is the upper threshold value for identifying characteristics with low values in group M but high values in group F.
- the value in $[-0.1;\ 0.1]$ is the threshold for identifying the most similar characteristics in both groups (Fig. 4).

The results were exported to separate Excel spreadsheets for further study. It is advisable to make similar comparisons between the control and experimental groups of users of social internet services. Thresholds can be modified.

The characteristics with higher values in the M group of users of social internet services than specific characteristics of the F group are shown in the table below. After analyzing this data, we draw the following conclusions: Men in the control group have very high values of the characteristics (Agreement, Time links, Indication of a person, event, etc.) of users of social internet services.

In contrast, these indicators are significantly lower in the female control group of users of social internet services. They are highlighted in Table 1.

There is no agreement among women's scores, which indicates that this indicator is likely to have a value close to the control group of men or at a similar level.

The Table 1 allows us to assess those characteristics with low values in the control group of women.

More than 20 unique characteristics in the female control group have relatively low scores, while 3 unique characteristics in the male control group have the highest possible scores.

The characteristics with higher values in the F group of users of social internet services than certain characteristics of the M group are shown in the table below. After analyzing this data, we can draw the following conclusions:

In the control group of women, the following characteristics are very high: Lack of Confidence, Agreement, Axiological modal judgments, and Politeness.

Table 1 Communication characteristics with a lower threshold value (control group of male characteristics)

Female features	Male features	Difference	Female values	Male values
Time links	**Agreement**	**−0.86821**	**0.131789**	**1**
Affirmation	Agreement	−0.81176	0.188242	1
Order	Agreement	−0.87794	0.122056	1
Long words	Agreement	−0.89546	0.104536	1
Profanity	Agreement	−0.83901	0.160989	1
Reference to quantity, size	Agreement	−0.85458	0.145416	1
Indication of a person, event, etc	**Agreement**	**−0.9344**	**0.065602**	**1**
Indication of a person who speaks for themselves	Agreement	−0.90325	0.096749	1
Verbal fillers	Agreement	−0.91882	0.081176	1
Idioms and Phraseology	Time links	−0.84137	0.013043	0.854413
Idioms and phraseology	Indication of a person, event, etc	−0.80497	0.013043	0.818016
Idioms and phraseology	Agreement	−0.98696	0.013043	1
Spatial language	Time links	−0.80828	0.046136	0.854413
Spatial language	Agreement	−0.95386	0.046136	1
Euphemisms	Time links	−0.80244	0.051976	0.854413
Euphemisms	Agreement	−0.94802	0.051976	1
Geographical references	Time links	−0.83164	0.022776	0.854413
Geographical references	Agreement	−0.97722	0.022776	1
Oaths	Time links	−0.85441	0	0.854413
Oaths	Indication of a person, event, etc	−0.81802	0	0.818016
Oaths	Agreement	−1	0	1
Contrasting	Agreement	−0.83706	0.162936	1
Paraphrasing	Time links	−0.84332	0.011096	0.854413
Paraphrasing	Indication of a person, event, etc	−0.80692	0.011096	0.818016
Paraphrasing	Agreement	−0.9889	0.011096	1
Indirect orders and requests	Agreement	−0.82149	0.178509	1
Impersonal expressions	Agreement	−0.82344	0.176562	1

(continued)

Table 1 (continued)

Female features	Male features	Difference	Female values	Male values
Direct quoting	Agreement	−0.91493	0.085069	1
Elliptical sentences	Agreement	−0.83512	0.164882	1

The same characteristics of the control male group are highlighted in yellow for comparison purposes. This is only a unique characteristic—lack of confidence, which equals 0.090082 in the male group. While in the female group, this value is higher and amounts to 0.844267.

Such characteristics as agreement, axiological modal judgments, and politeness are not present in Table 2. This indicates that the male control group of users of social internet services is not very low, and the difference between them and the female indicators is less than the upper threshold.

The Table 2 allows us to assess those characteristics with low values in the control group of men.

More than 27 unique characteristics in the male control group of users of social internet services have relatively low scores, while 4 unique characteristics in the female control group of users of social internet services have the highest scores; among them, Politeness is the leader.

The characteristics with similar values in control groups F and M of users of social internet services are shown in the table below. After analyzing this data, we can draw the following conclusions: 73 observations confirmed similar characteristics between the male and female control groups of users of social internet services. If we look at the descriptive statistics of this dataset (Fig. 5), they are almost identical for the groups of men and women.

The 40 unique characteristics of the control group of men and the 33 unique characteristics of the control group of women are similar in value.

Table 3 does not include cases where two identical characteristics of men and women have very close values.

The ten characteristics with the closest values are highlighted separately in Table 4 below.

Software-based gender identification is essential in fields [43] as diverse as advertising, social media, security services, online stores, law enforcement, and sociology. It allows advertisers to customize campaigns based on audience gender, analyze user profiles for gender-specific recommendations, and detect potential threats. Specialized agencies use it for investigative purposes, online stores optimize interfaces for different genders, law enforcement uses it to identify threats, and sociologists analyze large amounts of data to study digital gender trends. The ethical issues are addressed to protect users' privacy and confidentiality while complying with legal requirements and maintaining transparency.

Further exploration of the data will allow us to find additional patterns and study the specifics of communication between men and women on the Internet.

Table 2 Communication characteristics with a lower threshold value (control group characteristics of women)

Female features	Male features	Difference	Female values	Male values
Lack of confidence	Verbal fillers	0.839717	0.844267	0.00455
Lack of confidence	Idioms and phraseology	0.844267	0.844267	0
Lack of confidence	Reinforced meaning	0.817879	0.844267	0.026388
Lack of confidence	Mentioning of past events	0.825159	0.844267	0.019108
Lack of confidence	Expression of support	0.80878	0.844267	0.035487
Lack of confidence	Contrasting	0.821519	0.844267	0.022748
Lack of confidence	Direct quoting	0.839717	0.844267	0.00455
Axiological modal judgments	Verbal fillers	0.800784	0.805334	0.00455
Axiological modal judgments	Idioms and phraseology	0.805334	0.805334	0
Axiological modal judgments	Direct quoting	0.800784	0.805334	0.00455
Politeness	Apology	0.811647	1	0.188353
Politeness	answer evasion	0.909918	1	0.090082
Politeness	Order	0.855323	1	0.144677
Politeness	Long words	0.853503	1	0.146497
Politeness	Adjective expressions without semantic meaning	0.846224	1	0.153776
Politeness	Conditionality of actions	0.955414	1	0.044586
Politeness	Indication of a person who speaks for themselves	0.846224	1	0.153776
Politeness	Verbal fillers	0.99545	1	0.00455
Politeness	Idioms and phraseology	1	1	0
Politeness	**Lack of confidence**	**0.909918**	**1**	**0.090082**
Politeness	Accentuation	0.820746	1	0.179254
Politeness	Reinforced meaning	0.973612	1	0.026388
Politeness	Euphemisms	0.873521	1	0.126479
Politeness	Indication on multiple interlocutors	0.855323	1	0.144677
Politeness	Reduced-caressing forms	0.920837	1	0.079163
Politeness	Mentioning of past events	0.980892	1	0.019108
Politeness	Exclamatory intonation	0.818926	1	0.181074
Politeness	Expression of support	0.964513	1	0.035487

(continued)

Table 2 (continued)

Female features	Male features	Difference	Female values	Male values
Politeness	Contrasting	0.977252	1	0.022748
Politeness	Paraphrasing	0.915378	1	0.084622
Politeness	Indirect orders and requests	0.933576	1	0.066424
Politeness	Implication	0.904459	1	0.095541
Politeness	Meaningless expressions	0.917197	1	0.082803
Politeness	Questions	0.951774	1	0.048226
Politeness	Separation sentence	0.917197	1	0.082803
Politeness	Direct quoting	0.99545	1	0.00455
Politeness	Justification	0.946315	1	0.053685
Agreement	Answer evasion	0.851518	0.9416	0.090082
Agreement	Conditionality of actions	0.897014	0.9416	0.044586
Agreement	Verbal fillers	0.937051	0.9416	0.00455
Agreement	Idioms and phraseology	0.9416	0.9416	0
Agreement	**Lack of confidence**	**0.851518**	**0.9416**	**0.090082**
Agreement	Reinforced meaning	0.915213	0.9416	0.026388
Agreement	Euphemisms	0.815122	0.9416	0.126479
Agreement	Reduced-caressing forms	0.862437	0.9416	0.079163
Agreement	Mentioning of past events	0.922492	0.9416	0.019108
Agreement	Expression of support	0.906113	0.9416	0.035487
Agreement	Contrasting	0.918852	0.9416	0.022748
Agreement	Paraphrasing	0.856978	0.9416	0.084622
Agreement	Indirect orders and requests	0.875176	0.9416	0.066424
Agreement	Implication	0.846059	0.9416	0.095541
Agreement	Meaningless expressions	0.858798	0.9416	0.082803
Agreement	Questions	0.893374	0.9416	0.048226
Agreement	Separation sentence	0.858798	0.9416	0.082803
Agreement	Direct quoting	0.937051	0.9416	0.00455
Agreement	Justification	0.887915	0.9416	0.053685

```
B [94]: almost_equal_scores.describe()
```

Out[94]:

	Diff	Female Values	Male Values
count	73.000000	73.000000	73.000000
mean	-0.000100	0.168746	0.168846
std	0.005864	0.183262	0.183783
min	-0.009844	0.000000	0.000000
25%	-0.004550	0.051976	0.053685
50%	-0.000111	0.122056	0.126479
75%	0.005906	0.188242	0.188353
max	0.009159	1.000000	1.000000

Fig. 5 Descriptive statistics of numerical values with minimal difference between men and women in the control groups

Previous studies on the gender dimensions of online communication have provided valuable insights, but there are gaps in the current literature. These include a lack of research on the communication patterns and experiences of individuals with different gender identities, cultural variations in gendered communication, and the evolutionary trajectory of gendered online communication. A longitudinal study could provide significant insights into the intricacies of gendered communication by identifying developments, trends, or emerging patterns over different time intervals. The researchers provide a cursory examination of how gender intersects with socioeconomic status, race, and ethnicity, but more research is needed to understand how these intersecting identities affect individuals' online experiences. There is a lack of literature on the potential dangers and ethical dilemmas of collecting and using gender data, and more research is needed on privacy, data security, and the ethical use of gender data in digital environments.

There is a lack of literature on cases of empowerment and positive aspects of online platforms, such as facilitating constructive gender-related endeavors, activism, and community development. By incorporating these research areas into future efforts, we can improve our comprehensive and nuanced understanding of the complex relationship between gender and digital communication.

Table 3 Communication characteristics with characteristics at the same level

Female features	Male features	Difference	Female values	Male Values
Apology	Elliptical sentences	−0.00821	0.454935	0.463148
Time links	Euphemisms	0.00531	0.131789	0.126479
Affirmation	Apology	−0.00011	0.188242	0.188353
Affirmation	Accentuation	0.008988	0.188242	0.179254
Affirmation	Exclamatory intonation	0.007168	0.188242	0.181074
Order	Euphemisms	−0.00442	0.122056	0.126479
Long words	Implication	0.008994	0.104536	0.095541
Profanity	Adjective expressions without semantic meaning	0.007213	0.160989	0.153776
Profanity	Indication of a person who speaks for themselves	0.007213	0.160989	0.153776
Adjective expressions without semantic meaning	Affirmation	−0.00555	0.495815	0.501365
Conditionality of actions	Spatial language	−0.00705	0.221335	0.228389
Conditionality of actions	Objections	0.003865	0.221335	0.21747
Sports-political, automobile technological-innovative vocabulary	Politeness	−0.00799	0.318668	0.326661
Reference to quantity, size	Order	0.000739	0.145416	0.144677
Reference to quantity, size	Long words	−0.00108	0.145416	0.146497
Reference to quantity, size	Adjective expressions without semantic meaning	−0.00836	0.145416	0.153776
Reference to quantity, size	Indication of a person who speaks for themselves	−0.00836	0.145416	0.153776
Reference to quantity, size	Indication on multiple interlocutors	0.000739	0.145416	0.144677
Indication of a person, event, etc	Indirect orders and requests	−0.00082	0.065602	0.066424
Indication of a person who speaks for themselves	Answer evasion	0.006667	0.096749	0.090082
Indication of a person who speaks for themselves	Lack of confidence	0.006667	0.096749	0.090082
Indication of a person who speaks for themselves	Implication	0.001208	0.096749	0.095541
Verbal fillers	Answer evasion	−0.00891	0.081176	0.090082
Verbal fillers	Lack of confidence	−0.00891	0.081176	0.090082
Verbal fillers	Reduced-caressing forms	0.002013	0.081176	0.079163
Verbal fillers	Paraphrasing	−0.00345	0.081176	0.084622

(continued)

Table 3 (continued)

Female features	Male features	Difference	Female values	Male Values
Verbal fillers	Meaningless expressions	−0.00163	0.081176	0.082803
Verbal fillers	Separation sentence	−0.00163	0.081176	0.082803
Idioms and Phraseology	Verbal fillers	0.008493	0.013043	0.00455
Idioms and Phraseology	Mentioning of past events	−0.00607	0.013043	0.019108
Idioms and Phraseology	Contrasting	−0.00971	0.013043	0.022748
Idioms and Phraseology	Direct quoting	0.008493	0.013043	0.00455
Spatial language	Conditionality of actions	0.00155	0.046136	0.044586
Spatial language	Questions	−0.00209	0.046136	0.048226
Spatial language	Justification	−0.00755	0.046136	0.053685
Politeness	Agreement	0	1	1
Reinforced meaning	Geographical references	0.006136	0.423788	0.417652
Euphemisms	Conditionality of actions	0.00739	0.051976	0.044586
Euphemisms	Questions	0.00375	0.051976	0.048226
Euphemisms	Justification	−0.00171	0.051976	0.053685
Geographical references	Reinforced meaning	−0.00361	0.022776	0.026388
Geographical references	Mentioning of past events	0.003668	0.022776	0.019108
Geographical references	Contrasting	2.80E−05	0.022776	0.022748
Reduced-caressing forms	Oaths	0.008221	0.260269	0.252047
Oaths	Verbal fillers	−0.00455	0	0.00455
Oaths	Idioms and phraseology	0	0	0
Oaths	Direct quoting	−0.00455	0	0.00455
Mentioning of past events	Politeness	−0.00799	0.318668	0.326661
Contrasting	Adjective expressions without semantic meaning	0.009159	0.162936	0.153776
Contrasting	Indication of a person who speaks for themselves	0.009159	0.162936	0.153776
Paraphrasing	Verbal fillers	0.006546	0.011096	0.00455
Paraphrasing	Mentioning of past events	−0.00801	0.011096	0.019108
Paraphrasing	Direct quoting	0.006546	0.011096	0.00455
Indirect orders and requests	Apology	−0.00984	0.178509	0.188353
Indirect orders and requests	Accentuation	−0.00075	0.178509	0.179254
Indirect orders and requests	Exclamatory intonation	−0.00256	0.178509	0.181074
Impersonal expressions	Accentuation	−0.00269	0.176562	0.179254
Impersonal expressions	Exclamatory intonation	−0.00451	0.176562	0.181074

(continued)

Table 3 (continued)

Female features	Male features	Difference	Female values	Male Values
Clarifications	Oaths	0.008221	0.260269	0.252047
Discussion of current problems and topical issues	Spatial language	−0.00705	0.221335	0.228389
Discussion of current problems and topical issues	Objections	0.003865	0.221335	0.21747
Questions	Sports-political, automobile technological-innovative vocabulary	−0.00159	0.780027	0.78162
Questions	Discussion of current problems and topical issues	−0.00159	0.780027	0.78162
Separation sentence	Modal constructions	0.000473	0.308935	0.308462
Separation sentence	Socio-family language	0.007752	0.308935	0.301183
Direct quoting	Answer evasion	−0.00501	0.085069	0.090082
Direct quoting	Lack of confidence	−0.00501	0.085069	0.090082
Direct quoting	Reduced-caressing forms	0.005906	0.085069	0.079163
Direct quoting	Paraphrasing	0.000447	0.085069	0.084622
Direct quoting	Meaningless expressions	0.002267	0.085069	0.082803
Direct quoting	Separation sentence	0.002267	0.085069	0.082803
Humor	Mention of emotions and feelings	−0.00292	0.396535	0.399454
Justification	Clarifications	−0.00854	0.338135	0.346679

4 Conclusions

This research paper highlights the importance of identifying the gender of online users and its various benefits for consumers and online services. The paper examines various methods of gender identification, with a particular focus on network models that have proven effective in understanding online communication patterns and associations. The analysis of a dataset is carried out by providing descriptive statistics and visualizations. The comparison between control groups (F and M) of users of social internet services and experimental groups (F1 and M1) reveals exciting insights into the linguistic characteristics associated with gender. Women tend to score higher on certain communication traits, while men show strengths in other aspects.

The research extends to identifying specific communication traits with significant gender differences. Tables and graphs illustrate the differences, allowing for a

Table 4 Ten characteristics with the lowest level of deviation

Female features	Male features	Difference	Female values	Male values
Indication of a person, event, etc	Indirect orders and requests	−0.00082	0.065602	0.066424
Indirect orders and requests	Accentuation	−0.00075	0.178509	0.179254
Affirmation	Apology	−0.00011	0.188242	0.188353
Politeness	Agreement	0	1	1
Oaths	Idioms and phraseology	0	0	0
Geographical references	Contrasting	2.80E−05	0.022776	0.022748
Direct quoting	Paraphrasing	0.000447	0.085069	0.084622
Separation sentence	Modal constructions	0.000473	0.308935	0.308462
Reference to quantity, size	Order	0.000739	0.145416	0.144677
Reference to quantity, size	Indication on multiple interlocutors	0.000739	0.145416	0.144677

nuanced understanding of how linguistic features differ between male and female online communication.

The importance of software-based gender identification of users of social internet services in diverse settings and acknowledging the ethical considerations surrounding user privacy and transparency are discussed. Additional data exploration is necessary to discern additional patterns and comprehend the complexities of gendered online communication. Through the provision of an exhaustive examination of the complex correlation between generation and digital communication of users of social internet services, this paper establishes a foundation for subsequent investigations in this dynamic domain.

Acknowledgements This work was supported by the Disrupted Ukrainian Scholars and Students (DUSS) initiative at the University of Alberta.

References

1. Barlińska, J., Szuster, A., Winiewski, M.: Cyberbullying among adolescent bystanders: role of the communication medium, form of violence, and empathy. Commun. Appl. Soc. Psy. **23**, 37–51 (2013). https://doi.org/10.1002/casp.2137
2. Chai, S., Das, S., Rao, H.R.: Factors affecting bloggers' knowledge sharing: an investigation across gender. J. Manage. Inform. Syst. 309–341 (2011)
3. Iosub, D., Laniado, D., Castillo, C., Fuster Morell, M., Kaltenbrunner, A.: Emotions under discussion: gender, status and communication in online collaboration. PLoS ONE **9**, e104880 (2014)

4. Crocco, M.S., Cramer, J., Meier, E.B.: (Never) mind the gap! Gender equity in social studies research on technology in the twenty-first century. Multicult. Educ. Technol. J. **2**, 19–36 (2008). https://doi.org/10.1108/17504970810867133
5. Guiller, J., Durndell, A.: I totally agree with you': gender interactions in educational online discussion groups. Comput. Assist. Learn. **22**, 368–381 (2006). https://doi.org/10.1111/j.1365-2729.2006.00184.x
6. Hartsell, T.: Who's talking online? A descriptive analysis of gender & online communication. In: Information Communication Technologies: Concepts, Methodologies, Tools, and Applications, pp. 3529–3539. IGI Global (2008)
7. Kapidzic, S., Herring, S.C.: Gender, communication, and self-presentation in teen chatrooms revisited: have patterns changed? J. Comput.-Mediat. Commun. **17**, 39–59 (2011)
8. Li, Q.: Gender and CMC: A review on conflict and harassment. Australas. J. Educ. Technol. **21** (2005)
9. Li, S., Coduto, K.D., Morr, L.: Communicating social support online: the roles of emotional disclosures and gender cues in support provision. Telematics Inform. **39**, 92–100 (2019)
10. Manago, A.M., Graham, M.B., Greenfield, P.M., Salimkhan, G.: Self-presentation and gender on MySpace. J. Appl. Dev. Psychol. **29**, 446–458 (2008)
11. Mansell, R., Raboy, M.: The Handbook of Global Media and Communication Policy, 1st edn. Wiley (2011). https://doi.org/10.1002/9781444395433
12. Marshall, J.P.: Gender in online communication. In: Handbook of Research on New Literacies. Routledge, pp. 491–520 (2014)
13. Owen, J.E., Yarbrough, E.J., Vaga, A., Tucker, D.C.: An investigation of the effects of gender and preparation on quality of communication in Internet support groups. Comput. Hum. Behav. **19**, 259–275 (2003)
14. Pavan, E.: Internet intermediaries and online gender-based violence. Gender, Technol. Violence 62–78 (2017)
15. Prinsen, F.R., Volman, M.L.L., Terwel, J.: Gender-related differences in computer-mediated communication and computer-supported collaborative learning. Comput. Assist. Learn. **23**, 393–409 (2007). https://doi.org/10.1111/j.1365-2729.2007.00224.x
16. Royal, C.: A meta-analysis of journal articles intersecting issues of internet and gender. J. Tech. Writ. Commun. **35**, 403–429 (2005). https://doi.org/10.2190/3RBM-XKEQ-TRAF-E8GN
17. Buchmüller, S., Joost, G., Bessing, N., Stein, S.: Bridging the gender and generation gap by ICT applying a participatory design process. Pers. Ubiquit. Comput. **15**, 743–758 (2011). https://doi.org/10.1007/s00779-011-0388-y
18. Mishra, S., Aggarwal, M., Yadav, S., Sharma, Y.: An automated model for sentimental analysis using long short-term memory-based deep learning model. Int. J. Eng. Manuf. (IJEM) **13**(5), 11–20 (2023). https://doi.org/10.5815/ijem.2023.05.02
19. Savicki, V., Kelley, M.: Computer mediated communication: gender and group composition. Cyberpsychol. Behav. **3**, 817–826 (2000). https://doi.org/10.1089/10949310050191791
20. Korobiichuk, I., Fedushko, S., Juś, A., Syerov, Y.: Methods of determining information support of web community user personal data verification system. In: Automation 2017. ICA 2017. Advances in Intelligent Systems and Computing, vol. 550, pp. 144–150. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-54042-9_13
21. Sethna, B.N., Hazari, S., Bergiel, B.: Influence of user generated content in online shopping: impact of gender on purchase behavior, trust, and intention to purchase. IJEMR **8**, 344 (2017). https://doi.org/10.1504/IJEMR.2017.087719
22. Juyal, A., Sharma, N., Rithya, P., Kumar, S.: An enhanced approach to recommend data structures and algorithms problems using content-based filtering. Int. J. Intell. Syst. Appl. (IJISA) **15**(5), 28–40 (2023). https://doi.org/10.5815/ijisa.2023.05.03
23. Abafogi, A.: Boosting Afaan Oromo named entity recognition with multiple methods. Int. J. Inform. Eng. Electron. Bus. (IJIEEB) **13**(5), 51–59 (2021). https://doi.org/10.5815/ijieeb.2021.05.05
24. Sichler, A., Prommer, E.: Gender differences within the German-language Wikipedia. ESSACHESS-J. Commun. Stud. **7**, 77–93 (2014)

25. Kavoura, A., Stavrianea, A.: Following and belonging to an online travel community in social media, its shared characteristics and gender differences. Procedia Soc. Behav. Sci. **175**, 515–521 (2015)
26. Asmus, N., Masgutova, M., Zabolotneva, O.L.: Linguistic features of gender differences in blog communication. In: X International Conference "Word, Utterance, Text: Cognitive, Pragmatic and Cultural Aspects," pp. 45–52 (2020). https://doi.org/10.15405/epsbs.2020.08.6
27. Guiller, J., Durndell, A.: Students' linguistic behavior in online discussion groups: does gender matter? Comput. Hum. Behav. **23**, 2240–2255 (2007)
28. Thelwall, M., Wilkinson, D., Uppal, S.: Data mining emotion in social network communication: gender differences in MySpace. J. Am. Soc. Inf. Sci. **61**, 190–199 (2010). https://doi.org/10.1002/asi.21180
29. Zhang, R., Fu, J.S.: Privacy management and self-disclosure on social network sites: the moderating effects of stress and gender. J. Comput.-Mediat. Commun. **25**, 236–251 (2020)
30. Rollero, C., Daniele, A., Tartaglia, S.: Do men post and women view? The role of gender, personality and emotions in online social activity. Cyberpsychology: J. Psychosoc. Res. Cyberspace **13** (2019)
31. Chai, C., Wu, X., Shen, D., Li, D., Zhang, K.: Gender differences in the effect of communication on college students' online decisions. Comput. Hum. Behav. **65**, 176–188 (2016)
32. Suzuki, S.: Gender-linked differences in informal argument: analyzing arguments in an online newspaper1. Women's Stud. Commun. **29**, 193 (2006)
33. Hargittai, E., Shaw, A.: Mind the skills gap: the role of Internet know-how and gender in differentiated contributions to Wikipedia. Inf. Commun. Soc. **18**, 424–442 (2015). https://doi.org/10.1080/1369118X.2014.957711
34. Sultan, T., Jahan, N., Basak, R., Jony, M., Nabil, R.: Machine learning in cyberbullying detection from social-media image or screenshot with optical character recognition. Int. J. Intell. Syst. Appl. (IJISA) **15**(2), 1–13 (2023). https://doi.org/10.5815/ijisa.2023.02.01
35. Saha, S., Kumar, K.: Emoji prediction using emerging machine learning classifiers for text-based communication. Int. J. Math. Sci. Comput. (IJMSC) **8**(1), 37–43 (2022). https://doi.org/10.5815/ijmsc.2022.01.04
36. Teso, E., Olmedilla, M., Martínez-Torres, M.R., Toral, S.L.: Application of text mining techniques to the analysis of discourse in eWOM communications from a gender perspective. Technol. Forecast. Soc. Chang. **129**, 131–142 (2018)
37. Wu, J., Mattingly, E., Kraemer, P.: Communication in virtual environments: the influence of spatial cues and gender on verbal behavior. Comput. Hum. Behav. **52**, 59–64 (2015)
38. Zolduoarrati, E., Licorish, S.A.: On the value of encouraging gender tolerance and inclusiveness in software engineering communities. Inf. Softw. Technol. **139**, 106667 (2021)
39. Zhao, T., Tseng, C.L.: A note on activity floats in activity-on-arrow networks. J. Oper. Res. Soc. **54**(12), 1296–1299 (2003)
40. Yang, Z.Y., Wang, Z.F.: Comparison between AON and AOA network diagrams. In: 2010 IEEE 17Th International Conference on Industrial Engineering and Engineering Management, pp. 1507–1509 (2010)
41. Fedushko, S.: Gendered Discourse in the Digital Realm: Dataset of 48 Gender Linguistic Patterns. IEEE Dataport (2024). https://doi.org/10.21227/xvfj-5q41
42. Deepa, B., Ramesh, K.: Epileptic seizure detection using deep learning through min max scaler normalization. Int. J. Health Sci. **6**, 10981–10996 (2022)
43. Barker, K., Jurasz, O.: Gender-Based Abuse Online: An Assessment of Law, Policy and Reform in England and Wales, pp. 529–544. The Palgrave Handbook of Gendered Violence and Technology. Springe, Cham (2021). https://doi.org/10.1007/978-3-030-83734-1_26

The Impact of the Coronavirus Pandemic on SMEs in Term of Customer Centricity in Slovakia and Hungary

Enikő Korcsmáros, Erika Seres Huszárik, Silvia Tóbiás Kosár, Ladislav Mura, and Bence Csinger

Abstract The purpose of the study is to examine the impact of the coronavirus pandemic on SMEs, with a particular focus on their customer centricity. In the theoretical approach, we explore role and importance of customer centricity, as well as changes in buying behavior, using scientific literature. In primary research phase, based on questionnaire survey, we present the effects of the pandemic using various statistical methods, with specific focus on corporate reliability, customer re-engagement, and encouraging repeat purchases. We can conclude that the more attention a company pays to reliability, the easier it can persuade customers to purchase their services and/or products. Companies that have experienced a crisis situation to a large extent are heavily focused on re-engaging their existing customers for repeat purchases. Companies that believe it is more challenging to persuade customers after the COVID-19 pandemic are looking to introduce new marketing tools in the hope of incentivizing purchases.

Keywords Impact of coronavirus pandemic · SMEs · Customer centricity · Buying behavior · Statistical methods · Corporate reliability · Customer re-engagement · Repeat purchases

E. Korcsmáros · E. S. Huszárik · S. T. Kosár · B. Csinger
Faculty of Economics and Informatics, J. Selye University, Bratislavská Cesta 3322, 945 01 Komárno, Slovakia
e-mail: korcsmarose@ujs.sk

E. S. Huszárik
e-mail: huszarike@ujs.sk

S. T. Kosár
e-mail: kosars@ujs.sk

B. Csinger
e-mail: csinger.bence@gmail.com

L. Mura (✉)
Faculty of Commerce, University of Economics in Bratislava, Dolnozemská cesta 1, 852 35 Bratislava, Slovakia
e-mail: ladislav.mura@euba.sk

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2024

P. Štarchoň et al. (eds.), *Data-Centric Business and Applications*, Lecture Notes on Data Engineering and Communications Technologies 213,
https://doi.org/10.1007/978-3-031-62213-7_8

1 Introduction

The coronavirus pandemic has fundamentally changed the lives of both businesses and individuals. In most cases, uncertainty dominated the lives and everyday routines of businesses and employees alike [1]. The pandemic often forced participants in the economy to adapt to changes. It is important to highlight that, in addition to customers, companies also had to prioritize the health protection of their employees. The outbreak had negative impact on both consumer and business confidence, potentially resulting in reduced consumption and investment. As a result, many companies struggled to adjust to the new circumstances. Since the pandemic significantly affected the daily lives of various economic actors, including households, it can be said that both demand and consumer behavior underwent significant changes. For companies aiming to adapt more quickly to the newly emerging market situation, it was necessary to closely monitor the dynamically shifting consumer needs. In order for organizations to achieve maximum growth and maximize their sustainability, it has been and will continue to be crucial to rethink their operational strategies. According to study by Dore et al. [2], customer experience has become extremely important nowadays. Companies have generally approached the desired customer experience by creating seamless and convenient customer journeys, allowing them to better meet their customers' needs. Organizations will make much greater efforts to satisfy their customers' primary needs. Building on this, customer centricity has become a key issue during the pandemic and is expected to continue to strengthen even after the pandemic. Various needs have intensified. If companies fail to meet them, there is a high likelihood of decline in the customer base. To retain customers, continuous monitoring of the evolving situation, introduction of new marketing tools, and implementation of strategies have become crucial. According to Engidaw [3], the most characteristic trend among small businesses during the pandemic was the utilization of internet-based opportunities. In reality, the tools offered by the internet served as a lifeline for small businesses, enabling them to ensure their operations. However, according to the OECD report [4], SMEs were particularly vulnerable to the shocks caused by the pandemic, as they were overrepresented in sectors such as tourism and other services that were heavily impacted. Several significant studies have demonstrated that SMEs were greatly affected during the pandemic [5, 6]. Based on this, our thesis examines the main tools utilized by companies to ensure successful sales and strengthen their customer-centric approach.

2 Theoretical Background

Customer-centricity is a widely discussed topic among researchers as well as corporate leaders. It is clear that customer orientation has numerous positive implications, allowing companies to significantly increase their profits and, in certain cases, even create a competitive advantage over their rivals in the market [7], The COVID-19

pandemic has significantly amplified the role of customer-centricity, and customers now tend to choose companies that go above and beyond to meet their needs at the highest level of quality. It is evident that satisfied and loyal customers are easier and more cost-effective to retain and are more likely to engage in repeat purchases compared to new customers. Due to the impact of the COVID-19 pandemic, the importance of customer-centricity has undeniably strengthened both among the companies and the customers. In our terms, customer-centricity is crucial for companies to maximize customer satisfaction. From the perspective of companies, it is extremely important to delve deeper into customer expectations and satisfaction in order to adjust and potentially improve their customer-centricity. To achieve this, continuous monitoring of customer satisfaction is necessary as these analyses provide valuable insights for companies. According to Belandria [8], oversupply has placed the customer in a central role, where the efforts of companies are solely focused on satisfying the customer. Companies that genuinely adopt a customer-oriented approach place customer values at the core of their objectives. Based on this, certain departments within the company are also operated based on this philosophy.

According to Hemel and Radmakers [9], companies that prioritize becoming customer-centric and make every effort to achieve this can gain significant advantages. They believe that companies should primarily motivate their employees and provide guidance to ensure that customers have positive experiences and form a favorable impression of the company and its customer-centric practices.

For companies following a customer-centric approach, it is crucial to ensure that they can deliver the best possible value to customers given the circumstances. According to Hughes et al. [10], it is worthwhile to focus on simple yet bold approaches that tangibly reinforce the key messages formulated and advertised by the company, contributing to customer-centricity. Building on the findings of the authors, it is important first to assess the current level of customer-centricity within the company to gain a comprehensive understanding of the tools that can contribute to achieve customer-centricity. Additionally, documenting and closely monitoring the entire customer lifecycle can be beneficial, as it provides crucial insights into the customer experience. Performing in-depth research analysis can yield positive results by deriving conclusions from the data that can guide informed decision-making within the company. Finally, companies need to consider both short-term and long-term developments to concentrate on achieving customer-centricity. According to Ulwick [11], becoming a customer-centric company is not easy, but it is not impossible either. The main goal for each employee is not to be a customer-centric expert, but rather understand and draw the appropriate conclusions from the relevant customer data. To achieve this, companies need to initiate customer-centric research processes that enable the collection of unique customer information that can be used for future value creation.

Fader [12] presents a somewhat different approach compared to the previous perspectives, as he believes that customer-centricity is mainly about successfully identifying the most valuable customers, and then apply all the possible tools to gain significant profit for the company. Subsequently, the company should strive to attract and acquire as many similar customers as possible. By retaining and

acquiring these customers, the company can gain significant strategic advantages over its competitors.

According to a study by Lake [13], Jančíková and Strážovská [41] or Csabay and Stehlíková [43], micro and small businesses tend to place a greater emphasis on developing customer-centric approaches in order to understand the needs of their customer base. Cradden [14] and Csabay et al. [44] suggests that many small and medium-sized enterprises (SMEs) may assume that customer satisfaction and establishing customer-centricity are primarily achievable and relevant to large corporations. However, it is undeniably important for SMEs to have a presence and maintain a focus on customer satisfaction and customer-centricity as well.

According to the article by Miller [15] published in the Harvard Business School online repository, observing customer behavior can be an effective strategy. It is worthwhile to monitor customer actions at each stage of the purchasing process and make informed business decisions [46, 47] based on the data and observations obtained. In our view, it may be beneficial to utilize the platform, where the company strives to establish a connection with customers, which can include various social media platforms. Through these online platforms, customer needs can be effectively assessed by observing social conversations, keywords, and hashtags. This allows the identification of emerging trends, which can inform relevant and well-timed business decisions.

Patel [16] highlights that providing high-quality customer service is another method through which a company can thoroughly assess customer needs. From a specific perspective, real-time support can be incredibly important to customers. The use of various chatbots allows companies to engage in live conversations with customers, providing real-time assistance during the sales process. Chatbots enable round-the-clock communication, but it is important to consider the limitations of this method as well. In many cases, customers have very specific requests that may not guarantee an appropriate response since chatbots typically operate based on predefined patterns. Despite this limitation, chatbots remain highly effective and rewarding, as they provide valuable insights to the company through the reception of various customer inquiries.

Rubkiewicz and Kowaska [17] suggest that conducting detailed competitor research can be an effective method for assessing customer needs. This approach involves identifying competitors' problems and desires, as it provides a simple way to uncover customer preferences and issues. For example, if a company offers a service that is also provided by its competitors, it can be valuable to investigate the complaints and feedback from customers who have used the service. This information can be used to improve and further develop the service offered. By understanding the shortcomings of competitors and addressing them in their own offerings, companies can better meet customer needs and gain a competitive advantage.

Caliskan-Esmer [18] and Ďuriš et al. [42] emphasizes that companies are placing greater emphasis on customer-centricity to stay connected with new trends. Relationship marketing can be a useful tool in this regard, as it helps build stronger connections with customers, which is essential for survival in the current market environment. According to Minguez-Sese [19], relationship marketing can be a key

factor in companies' strategies, as it leads to higher levels of customer commitment and loyalty. Referring to the findings of Sedalo et al. [20], the application of relationship marketing significantly contributes to brand reputation and customer acquisition, as it encourages repeat purchases. In our view, by utilizing relationship marketing, companies aim to retain their existing customers and strengthen their satisfaction. Building long-term relationships is a clear objective of this approach. To achieve this, companies often conduct post-purchase surveys through various platforms and provide other post-purchase services.

Yo-Campos [21] suggests that the increasing availability and accessibility of data can provide professionals with higher quality information, enabling them to make better strategic decisions. This data and information allow them to better understand customer behaviors and preferences, which play an essential role in developing effective relationship marketing strategies. By leveraging these insights, companies can tailor their marketing efforts to align with customer needs and expectations, ultimately enhancing customer satisfaction and loyalty.

Gilboa et al. [22] share a similar viewpoint, stating that small businesses can create a key competitive advantage over other small businesses in the market by offering personalized services. To achieve this, they encourage these businesses to store important customer information, including their purchases, in a database. With this data, they can make decisions that enable them to provide highly personalized services or products, which in turn increases trust and loyalty. Based on this data, the relationship marketing strategy can be improved according to specific customer needs, maximizing its effectiveness and success.

Firdaus and Kanyan [23] propose four main categories of relationship marketing. The first step is trust, where the company focuses on building trust with both employees and customers. In both cases, participants should be aware of their responsibilities and be able to rely on each other. This is followed by communication, which can be approached from two sides: effective information transmission from the seller's side and effective communication of individual needs and feedback from the buyer's side. However, we believe that companies need to take initiative to encourage customers to provide feedback on their shopping experiences and overall satisfaction. The third category is empathy, wherein the company strives to understand and assess the needs of its customers and aims to find rational solutions to address any dissatisfaction that may arise. The last category is commitment, which requires both parties to be willing to establish a strong relationship. Both the buyer and the seller need to make efforts to create a fruitful relationship that can be shaped into a positive outcome according to their respective needs.

During the coronavirus pandemic, consumers' attitudes and purchasing habits underwent significant changes, and it is likely that a portion of this new mindset will remain even after the pandemic subsides. According to a press release from the European Commission in 2021, 71% of consumers made online purchases in 2020. Furthermore, 42% of consumers considered postponing major purchases, while 80% had no travel plans until the situation improves. During their purchases, 56% of consumers took various environmental factors into account, and 67% stated that they bought products with a lower environmental impact, even if the price of the product

significantly increased. Additionally, 81% of consumers supported local businesses by making purchases closer to home whenever feasible. The aforementioned data is supported by Sinclair's [24] research, which indicates a significant increase in "near me" type searches based on user search interests, as consumers sought to meet their needs locally. Tao et al. [25] suggest that consumers experience various psychological changes during challenging times, which tangibly influence their purchasing behavior. In such times, hoarding, panic buying, impulse buying, compulsive buying, and a preference for online shopping may come to the forefront. According to Pantano and Willems [26], increased shopping and impulsive and compulsive buying can lead to dependency and financial difficulties [45]. On the other hand, when individuals experience a crisis, there is a greater chance that they will carefully consider their expenses and purchasing habits, and potentially strive not only for rational decision-making but also for more sustainable choices. Das et al. [27] suggest that individuals who have experienced a pay cut or job loss have become quite active in practicing yoga and purchasing herbal remedies. These facts indicate that people will pay much greater attention to preserving their health in the future.

According to Sinclair's [24] analysis for Google, it can be said that during the COVID-19 period, there was a significant increase in interest in virtual alternatives. Furthermore, consumers became incredibly concerned about obtaining accurate information about the products, making it particularly necessary for merchants to keep the information about their offered products or services up to date. These factors should be taken into account by companies as continuous monitoring of consumer changes can facilitate the introduction of innovations. It may be worth considering the use of QR codes, the introduction of applications and virtual alternatives, as there is a clear increase in demand for these based on research data. Considering the study by Sinclair and Moneta [28], the consequences of the pandemic have clearly accelerated the development of the digital world. New digital habits have also emerged in the area of consumer behavior, which will continue to evolve in the coming years. Since different countries are currently in various stages of economic recovery, this presents a suitable opportunity for companies to think big and change their business activities to meet the new digital expectations. What is certain is that the default shopping platform has become the online space. Since the beginning of March 2020, global interest in online shopping has doubled. Aronson [29] shares a similar opinion, as he believes that leaders need to understand the underlying reasons for individual needs and personal preferences and how these factors will influence consumers, their lifestyles, and spending habits. Building a relationship with customers will be incredibly important after this period. Click-and-collect, which combines online and offline interactions, enabling online shopping and human contact, can play a significant role in sales methods in the coming years.

Bilková et al. [30] found that over half of the consumers in Slovakia have changed their shopping habits during the pandemic. These changes primarily focused on shopping sizes, as consumers opted for larger purchases instead of multiple smaller ones, leading to shift in shopping frequency. Due to various mobility restrictions, about one-third of consumers were engaged in stockpiling. One of their most important findings reflects the emergence of a new phenomenon due to the pandemic, as more

than one-fifth of respondents stated that they will never return to their pre-pandemic habits. According to Behúňová [31], in the second half of 2020, the value of card payments exceeded cash withdrawals, which had previously been consistently higher than card payments. Furthermore, there was a significant increase in the transition to digital shopping, with consumers also preferring card payments. In the last quarter of 2020, the share of card payments reached 12.4%, nearly a 2% point increase compared to the first quarter of the same year. The research also reveals that in the third quarter of 2019, mobile payments accounted for a 3.7% share of all card payments. By the last quarter of 2020, this percentage had doubled, as the same payment method accounted for 7.8% share, showing continuous growth. Based on these data, it may be reasonable for businesses where card payments are not currently possible to consider introducing this method, as Slovak consumers have shown a shift towards digital payment methods. The research assumes that these mentioned trends will continue. In the study conducted by MasterCard, Big Fish, and Frontira [32], 1.000 participants were surveyed about the online shopping habits of Hungarian consumers. The results indicate that consumers love to shop from the comfort of their homes, with nearly 60% of respondents making purchases while lying in bed. According to the study, the circumstances in which consumers make purchases are closely related to the type of product they buy. For example, those making purchases from the bathroom primarily choose household products. 10% of the respondents stated that although they wanted to, they often couldn't prepay. These findings suggest that even after the first few waves of the pandemic, not every company was able to offer card subscriptions. Companies often believe that they face significant obstacles in reaching out to the older demographic group. However, the results of the research clearly reflect that this is no longer true, as the pandemic has impacted online shoppers of all age groups to such an extent that the category of weekly shoppers is led by those aged 55–60 with a 17% share. In a study conducted by PwC [33], more than 9.000 shoppers were surveyed in 25 different countries, and it can be concluded that 37% of shoppers purchase from various companies in order to fully meet their needs. Consequently, the importance of customer-centricity is stronger than ever, as shoppers show a greater willingness to purchase from different sources. Building on another study by PwC [33], sustainability has clearly become more important to shoppers, likely influenced to a significant extent by the pandemic. Based on the results, it can be stated that companies capable of gaining the trust of shoppers and willing to invest the right amount to create a seamless shopping experience will gain significant advantages.

3 The Purpose and Methodology of the Research

The primary purpose of the research is to gain a comprehensive understanding of customer centricity, its attainment, and its tools from the perspective of SMEs in Slovakia and Hungary. Applying a questionnaire survey, we assessed the extent to which the COVID-19 pandemic has affected the companies in Slovakia and Hungary,

examining various aspects. The research employed a descriptive study design using a cross-sectional research method. A single sample was taken from the population, and data collection was carried out based on this sample. It is important to note that this research method does not allow the exploration of causal relationships. Within the quantitative research methodology, we utilized the option of questionnaire surveys, which were distributed via email to companies in our database, as well as made available in various online groups. The data collection period spanned from September 2021 to December 2022. Throughout the data collection process, a total of 545 responses were collected, with the distribution between the two countries as follows: Hungarian companies accounted for 45.50% (248 responses), while Slovakian companies accounted for 54.50% (297 responses).

In order to strengthen the validity of our findings, we conducted a representativeness calculation. However, it is important to note that due to the sample size, our research cannot be considered representative. The following formula was used in the calculation:

$$n = \frac{N * Z^2 * p * (1 - p)}{(N - 1) * e^2 + Z^2 * p * (1 - p)}$$

where N = total population, which according to the data from the Slovak Statistical Office and the Central Statistical Office is 1,335,102 companies, Z = critical value of 1.96 for a 95% confidence interval, P = expected participation rate of 40%, and d = margin of error of 5%. After performing the calculation, we determined that a total of 385 respondents are needed to strengthen our results. Following the survey period, we collected 545 responses, which further reinforces the findings. In the primary research, we presented the sample using various descriptive statistical tools, and subsequently conducted statistical tests to examine the hypotheses formulated, which are as follows:

1. The more attention a company pays to reliability, the easier it can convince customers to purchase its services and/or products.

   H0: There is no linear trend that can be identified between reliability and convincing customers to make a purchase.
   H1: A linear trend can be observed between reliability and convincing customers.

2. Companies that experienced a critical situation during COVID-19 pay greater attention to reactivating their existing customers.

   H0: There is no significant relationship observed between experiencing a critical situation and reactivating the existing customer base.
   H1: A significant relationship can be identified between experiencing a critical situation and reactivating the existing customer base.

3. Companies that believe it is much more challenging to persuade customers after the COVID-19 pandemic are looking to introduce new marketing tools in the hope of incentivizing them to make purchases.

   H0: There is no linear relationship between the introduction of new tools and the increased difficulty of convincing customers.
   H1: A linear relationship can be observed between the introduction of new tools and the increased difficulty of convincing customers.

We performed the Jonckheere-Terpstra trend test to examine the first hypothesis of our study, as we were investigating a linearly decreasing monotonic trend. It is important to note that the question formulated in the Likert scale we examined represented a positive trend. However, in the statistical software SPSS, we set up the test to analyze a decreasing trend to correctly conduct our hypothesis testing. In accordance with statistical rules, to ensure successful interpretation, it is necessary to establish six different conditions. In our case, all six conditions are met, which are as follows:

Based on the first condition, our dependent variable is an ordinal-level variable. According to the second condition, we can conclude that the independent variable has at least two groups since the data was measured on a Likert scale. Regarding the third assumption, the observations are independent as each respondent belongs to only one group. The fourth condition implies that the ordering of the independent variable's attributes has been established since we are dealing with data measured on a Likert scale, where 1 represents "strongly disagree" and 5 represents "strongly agree." As for the fifth assumption, we can state that the alternative hypothesis has been formulated in the correct direction, assuming a linearly decreasing trend. The sixth assumption requires us to examine the form of the ordinal independent variable's attributes since the Jonckheere-Terpstra test can only be performed for similar or equal forms. To test this assumption, we created histograms for both countries. Based on both histograms, we can conclude that the attributes have somewhat similar shapes, allowing us to conduct the test. However, the results will be evaluated based on the effects observed.

Based on these findings, the null hypothesis and the alternative hypothesis are modified as follows:

τnot at all characteristic = τsomewhat characteristic = τcannot decide = τhighly characteristic = τfully characteristic.

In this null hypothesis, τ represents the effect of the independent variable on the dependent variable, and the subscripts represent the groups of the independent variable. In null hypothesis, it can be stated that the effects of all groups of the independent variable on the dependent variable are equal within the studied population.

IF: τcompletely characteristic $\geq$ τhighly characteristic $\geq$ τundecided $\geq$ τslightly characteristic $\geq$ τnot characteristic at all.

At least one strict inequality, meaning that at least one group's median or effect is smaller than another group's median or effect. Based on this, the alternative hypothesis states that as the level of the independent variable increases, the median or strength of the effect decreases.

We applied the Chi-square test for our second hypothesis. In our analysis, we used the contingency table with the "re-engagement of customers" as a dependent variable and the "critical situation" as an independent variable. Both variables were measured at an ordinal level. We conducted the analysis using the Pearson chi-square test. Since a statistically significant relationship was found, we also conducted post hoc tests using the ADR method.

We conducted a Cochran-Armitage trend test to examine our third hypothesis. Two conditions must be met for the test, which are as follows: Firstly, there needs to be an independent ordinal variable, which is fulfilled in our case as the Likert scale data can be ordered. Secondly, a dichotomous dependent variable is required, which is also fulfilled in our case. Consequently, we are essentially examining whether there is a linear relationship between the variables under investigation.

4 The Purpose and Methodology of the Research

In terms of the composition of the sample, considering both countries, the highest proportion of respondents in the study consisted of limited liability companies. In the case of Slovakian respondents, this accounts for 60.94%, while for Hungarian respondents, the same category represents 55.87% of the sample. Furthermore, concerning the respondents from Hungary, 14.17% of them are registered as general partnerships, whereas in the other country, this accounts for 19.87%. In Hungary, 8.50% of the respondents are registered as joint-stock companies, while 6.48% are registered as limited partnerships. Regarding the proportions of individual entrepreneurs, it can be stated that Hungarian respondents account for 14.98%, whereas Slovakian respondents account for 19.19%.

In the survey, Slovakian companies are predominantly operating in accommodation services sector (15.20%), IT sector (14.19%), education (14.53%), and other services sector (13.85%). On the other hand, Hungarian companies are primarily active in transportation and storage sector (17.34%) and also in the IT sector (16.13%). Additionally, 8.06% of Hungarian companies operate in the construction industry, while 9.46% of Slovakian respondents are engaged in the same field.

The first hypothesis was tested using the Jonckheere-Terpstra trend test, which aimed to examine whether companies that prioritize reliability can more easily persuade customers to purchase their services and/or products.

The specific median values obtained during the test were provided for each group of the independent variable and the corresponding dependent variable (Table 1).

Based on the above table, in the case of Slovakia, we can say that the approach to customers in the reliability groups was 2.0 in the "not at all characteristic" group (n = 5), 1.5 in the "somewhat characteristic" group (n = 14), 0.0 in the "cannot decide" group (n = 0), 2.0 in the "highly characteristic" group (n = 163), and 3.0 in the "fully characteristic" group (n = 115). On the other hand, in the case of Hungary, it was 0.0 in the "not at all characteristic" group (n = 0), 0.0 in the "somewhat characteristic" group (n = 0), 0.0 in the "cannot decide" group (n = 0), 3.0 in the

Table 1 Median values—Slovakia, Hungary

Approaching customers				
Reliability	N—SK	Median	N-HU	Median
Not characteristic at all	5	2.00	0	0.00
Slightly characteristic	14	1.50	0	0.00
Cannot decide	0	0	0	0.00
Highly characteristic	163	2.00	42	3.00
Fully characteristic	115	3.00	206	3.00
Total	297		248	

Source own editing in the SPSS software based on primary data collection

"highly characteristic" group (n = 42), and 3.0 in the "fully characteristic" group (n = 206).

Based on the previous values, we assume that our monotonic trend follows a decreasing direction. The following Table 2 illustrates the statistical values for both countries.

In the case of Slovakia, based on the statistical value of −4.110, a decreasing linear monotonous trend can be observed, which is statistically significant as the two-sided significance level is $p < 0.001$. On the other hand, in the case of Hungary, this value is 0.533, and the two-sided significance level is $p > 0.001$.

As a result, it is necessary to examine the value of Kendall's tau-b in the case of Slovakia, which is shown in the following Table 3.

Based on the above table, in the case of Slovakia, the correlation value is −0.210, indicating a moderate negative monotonic trend between the two variables. This finding reinforces the results obtained from the Jonckheere-Terpstra trend test. According to the test, in Slovakia, it can be concluded that the more emphasis is placed on reliability, the easier it is to convince customers to purchase the service and/or product.

In the case of the second hypothesis of our research, we applied the Chi-square test. In this case, we examined whether companies that experienced a critical situation during the COVID-19 period pay more attention to reactivating existing customers. The following Table 4 illustrates the Chi-square test for both countries.

Table 2 Jonckheere-Terpstra statistical values

Slovakia		Hungary	
Total N	297	Total N	248
Statistical value	15.045	Statistical value	4.544.000
Standardized error	729.240	Standardized error	408.877
Standardized statistical value	−4.110	Standardized statistical value	0.533
Two-sided significance level	0.000	Two-sided significance level	0.594

Source own editing in the SPSS software based on primary data collection

Table 3 Kendall's tau-b values

			SK
Kendall's tau_b	Approaching customers	Correlation coefficient	1.000
		One-sided significance	
		N	297
	The importance of reliability	Correlation coefficient	−0.210
		One-sided significance	0.000
		N	297

Source own editing in the SPSS software based on primary data collection

Table 4 Chi-square test

	Value SK	Two—sided sig	Value HU	Two—sided sig
Chi-square	53.46	0.000	4.159	0.125
Likelihood ratio	63.31	0.000	6.632	0.036
Linear association	0.313	0.576	0.469	0.494
N of valid cases	184		76	

Source own editing in the SPSS software based on primary data collection

Based on the above table, a significant relationship can be observed between the two variables in the case of Slovakia, as the significance level is $p < 0.001$. In contrast, no significant relationship can be observed in the case of Hungary. Therefore, in the case of Slovakia, we further examine the value of the Gamma coefficient, which is shown in the following Table 5.

The value of the Gamma coefficient is 0.178, indicating a weak but statistically significant relationship between the two variables. Considering that a statistically significant relationship was found between the variables, we further examined the Adjusted Residuals to determine which attributes show the strongest association. Based on the values, we can conclude that those who experienced a crisis situation to a large extent or completely are highly focused on re-engaging their existing customers for repeat purchases.

In the case of the following hypothesis, we conducted the Cochran-Armitage trend test, starting with the elaboration of a contingency table. The results for Slovakia can be seen in the following Table 6:

Table 5 Gamma coefficient value for Slovakia

	Value SK	Error value SK	Sig. Level SK
Gamma	0.178	0.104	0.094
N	184		

Source own editing in the SPSS software based on primary data collection

Table 6 Cohran-Armitage cross table—Slovakia

			Crisis situation					Total
			Not at all	A little bit	Don't know	To a great extent	Completely	
New tool	Yes	Count	2	9	41	54	0	192
		% within critical	5.7%	16.7%	75.9%	53.5%	0.0%	64.4%
	No	Count	33	45	13	47	54	106
		% within critical	94.3%	83.3%	24.1%	46.5%	100.0%	35.6%
Total		Count	35	54	54	101	54	298
		% within critical	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source own editing in the SPSS software based on primary data collection

Despite the indication from the above contingency table of companies that experienced a critical situation during COVID-19 are not likely to work on introducing a new tool for stimulating purchases, we conducted the test to confirm or reject this.

Based on the above information, we also conducted the Cohran-Armitage trend test, which is shown in the following Table 7.

Based on the results in the above table, the following can be concluded for Slovakia: A Cohran-Armitage trend test was conducted to examine whether there is a linear relationship between experiencing a critical period and the introduction of new tools. The Cohran-Armitage trend test revealed a statistically significant linear relationship between the two variables, as $p < 0.001$.

In the case of Hungary, we followed the same procedure. For the Hungarian cross-tabulation, we obtained the following values: the frequency of experiencing a critical situation was 1—not at all characteristic ($n = 21$), 2—slightly characteristic ($n = 42$), 3—cannot decide ($n = 49$), 4—highly characteristic ($n = 38$), 5—fully characteristic ($n = 49$), while the willingness to introduce new tools had proportions of 1, 0.689, 0.891, 0.905, and 0.710, respectively. The value of the Cohran-Armitage

Table 7 Cohran-Armitage trend test

			Value	Sig
Step 0	Variable	Critical period	0.002	0.000
	Statistical values		0.002	0.000

Source own editing in the SPSS software based on primary data collection

trend test (1.376) also indicated a statistically significant relationship between the two variables, as $p < 0.001$.

5 Summary, Recommendation

Based on the results of the hypothesis testing in both countries, it can be concluded that companies that prioritize reliability are more likely to convince customers to purchase their services and/or products. To gain a broader understanding of these findings, we compared our research results with other international studies. In a quantitative study conducted by Ngaliman et al. [34], which also utilized a questionnaire survey, it was found that reliability has a direct impact on customer satisfaction. The study mainly focused on service-providing companies and revealed that if companies are able to exceed customer expectations slightly, there is a greater likelihood of customers evaluating the service positively.

Based on this and referring to the empirical findings of Johnson and Karlay [35], it can be stated that providing higher quality services increases the customer happiness and satisfaction significantly. In our view, when the customer base is more satisfied, it becomes much easier for the company to encourage repeat purchases from the already satisfied customers.

Referring to the insights of Akula [36], it is commonly observed that businesses tend to focus on acquiring new customers, often neglecting the importance of retaining the existing ones. However, equal attention should be given to retained customers as well. To achieve this, it is crucial to leverage modern technological tools and opportunities. This includes approaches such as "Machine Learning" and "Big Data Analysis", which are integral to harnessing the power of data. We believe that data has become an integral part of our daily lives, and by analyzing and researching it, we can gain deeper and more accurate insights into our business inquiries, leading to data-driven decision-making within the company. It is important to note that micro and small businesses may not always have the budget to employ a dedicated data analyst. However, whenever possible, it would be necessary to utilize these resources, as they can improve planning and enable more efficient achievement of set goals.

Based on our statistical analysis, it has been revealed that Slovakian companies that experienced a critical situation during the COVID-19, will pay greater attention to reactivating existing customers. In our opinion, one of the most cost-effective ways to generate revenue is undoubtedly retaining existing customers and reactivating them. By retaining customers, we can increase the number of repeat purchases and revenue levels. According to Ascarza et al. [37], companies need to utilize various metrics and measurement tools to gain a comprehensive understanding of customer retention. This includes metrics such as retention rate, which according to Reichheld [38], achieving a 5% increase in customer retention can lead to a 95% increase in profits. Small businesses can achieve a more cost-effective customer retention rate by utilizing opportunities such as community building. Becoming a pillar of the local community and integrating into the community can result in fruitful relationships.

Another important factor that small businesses can leverage in customer retention is a quick response time. If a dissatisfied customer receives a prompt solution or response to their problem, there is a chance to increase satisfaction.

Our findings also indicate that companies who believe it is more challenging to persuade customers following the COVID-19 pandemic are interested in implementing new marketing tools to incentivize purchases. The COVID-19 outbreak has clearly altered consumer shopping habits and demand. During these times, online shopping, impulse buying, stockpiling, panic buying, compulsive buying, patriotism, and environmental factors have come to the forefront. The changing purchasing behaviors make it more difficult for companies to reach out to customers. In such cases, it may be worthwhile to introduce new tools to enhance reach. According to Hoekstra and Leeflang [39], the COVID-19 period provided an opportunity for marketers and marketing researchers to study the transient and enduring effects of the pandemic on consumer behavior. By studying these effects, future marketing strategies and newly introduced tools can be determined more effectively. Koppala [40] argues that post-pandemic, emphasizing the company values is more critical than ever before. If a company's values align strongly with those of its customers, it is crucial to communicate them clearly and comprehensively. The author's perspective also aligns with community building, as it plays a pivotal role in reaching out to and retaining customers in the future.

References

1. Bálintová, M., Barcziová, A., Machová, R.: Labor market policy in the Slovak Republic and Hungary during the COVID-19 pandemic. In: Hradec Economic Days: Proceedings of the international scientific conference Hradec Economic Days 2022, pp. 20–29. Univerzita Hradec Králové, Hradec Králové [online]. ISBN 978-80-7435-855-5. ISSN 2464-6067. ISSN 2464-6059. https://doi.org/10.36689/uhk/hed/2022-01-002
2. Dore, F., Ehrlich, O., Malfara, D., Ungerman, K.: Connecting with customers in times of crisis. In: McKinsey Capabilities [online] (2020). [Cited 10 Sept 2022]. Retrieved from https://www.mckinsey.com/capabilities/growth-marketing-and-sales/our-insights/connecting-with-customers-in-times-of-crisis
3. Engidaw, A.E.: Small businesses and their challenges during COVID-19 pandemic in developing countries: in the case of Ethiopia. J. Innov. Entrep. **11**(1), (2022). [Cited 10 Sept 2022]. Retrieved from https://doi.org/10.1186/s13731-021-00191-3
4. OECD. Coronavirus (COVID-19): SME Policy Responses, p. 169. OECD Publishing (2020). Retrieved from https://read.oecd-ilibrary.org/view/?ref=119_119680-di6h3qgi4x&title=Covid-19_SME_Policy_Responses
5. Zsigmond, T., Machová, R., Zsigmondová, A.: Strategic management from the perspective of SMEs operating in service sector. Qual. Innov. Prosper. **25**(2), 37–53 (2021). https://doi.org/10.12776/qip.v25i2.1549
6. Zsigmond, T., Kovács, A., Zakrzewska, M.: The economic and labour market effects of the covid-19 epidemic–the case of v4 countries. In: Langhamrová, J., Vrabcová, J. (eds.) RELIK 2022: Reproduction of Human Capital—Mutual Links and Connections, pp. 891–900
7. Barcziová, A., Machová, R.: Methods of education during the pandemic in the context of demography. In: RELIK 2021: Conference Proceedings. Praha: Prague University of Economics and Business, pp. 41–50 (2021) [online]. ISBN 978-80-245-2429-0

8. Belandria, J.: What is customer orientation and why is it important for your company? In; TechBlog. (2022) [online]. [Cited 11 Sept 2022]. Retrieved from https://www.gb-advisors.com/what-is-customer-orientation-and-why-is-it-important-for-your-company/
9. Hemel, C.V.D., Rademakers, M.: Building customer-centric organizations: shaping factors and barriers. J. Creat. Value. **2**(2), (2016). [cited 10 Sept 2022]. Retrieved from https://www.researchgate.net/publication/304713939_Building_Customer-centric_Organizations_Shaping_Factors_and_Barriers
10. Hughes, C. et al.: Customercentricity embedding it into your organisation's DNA. In: Deloitte—Leading Business Advisers (2014). [cited 10 Sept 2022]. Retrieved from https://www2.deloitte.com/content/dam/Deloitte/ie/Documents/Strategy/2014_customer_centricity_deloitte_ireland.pdf
11. Ulwick, A.W.: Blueprint for building a customer-centric culture of innovation. In: Strategyn (2015). [online]. [cited 10 Sept 2022]. Retrieved from https://strategyn.com/wp-content/uploads/2019/10/Blueprint-for-Building-a-Customer-Centric-Culture-of-Innovation-Strategyn.pdf
12. Fader, P.: Focus on the right customers for strategic advantage. Wharton Executive Essentials 129 (2012). ISBN 978-1-61363-016-7
13. Lake, R.: How to make your small business more successful. In: Operations & Success (2022). [online]. [cited 13 Sept 2022]. Retrieved from https://www.thebalancemoney.com/how-to-make-your-small-business-more-successful-4060804
14. Cradden, J.: How to make 'Customer Success' work for SMEs. In: ThinkBusiness (2022). [cited 13 Sept 2022]. Retrieved from https://www.thinkbusiness.ie/articles/making-customer-success-work-smes/
15. Miller, K.: 3 methods for identifying & leveraging your customers' needs. In: Harvard Business School Online—Business Insights (2020). [cited 13 Sept 2022]. Interneten elérhető https://online.hbs.edu/blog/post/methods-for-identifying-customer-needs/
16. Patel, S.: 7 effective methods to identify and meet customer needs. In: CustomerNeeds (2022). [cited 14 Sept 2022]. Retrieved from https://www.revechat.com/blog/customer-needs/
17. Rubkiewicz, A., Kowalska, K.: How to identify customer needs—a step by step approach. In: Success (2021). [cited 14 Sept 2022]. Interneten elérhető https://www.livechat.com/success/identify-customer-needs/
18. Caliskan, A., Esmer, S.: Does it really worth investing in relationship marketing for a port business? Case Stud. Transp. Policy. **7**(2), (2019). [Cited 15 Sept 2022]. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S2213624X17302146
19. Minguez, A., Sese, F.J.: Why do you want a relationship, anyway? Consent to receive marketing communications and donors' willingness to engage with nonprofits. J. Bus. Res. **148**, (2022). [Cited 16 Sept 2022]. Retrieved from https://www.sciencedirect.com/science/article/pii/S0148296322003915
20. Sedalo, G., Boaten, G.H., Kosiba, J.P.: Exploring social media affordance in relationship marketing practices in SMEs. Digit. Bus. **2**(1), (2022). [cited 16 Sept 2022]. Retrieved from https://www.sciencedirect.com/science/article/pii/S2666954421000168
21. Yo, F.Y., Campos, N.: Blending internet-of-things (IoT) solutions into relationship marketing strategies. Technol. Forecast. Soc. Chang. **137**, (2018). [cited 17 Sept 2022]. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S0040162518306334
22. Gilboa, S., Guttman, S.T., Mimran, O.: The unique role of relationship marketing in small businesses' customer experience. J. Retail. Consum. Serv. **51** (2019). [cited 18 Sept 2022]. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S0969698918310907
23. Firdaus, A., Kanyan, A.: Managing relationship marketing in the food service industry. Mark. Intell. Plan. **32**(3), (2014). [cited 17 Sept 2022]. Retrieved from https://www.deepdyve.com/lp/emerald-publishing/managing-relationship-marketing-in-the-food-service-industry-jugZEobltU
24. Sinclair, L.: Search insights to help you understand consumers: The U.K. saw rises in 'ways to help' and 'shops near me'. Consum. Insights (2020). [cited 28 Sept 2022]. Retrieved from https://www.thinkwithgoogle.com/intl/en-gb/consumer-insights/consumer-trends/covid-shopping-behaviour-insights/

25. Tao et al.: The impact of consumer purchase behavior changes on the business model design of consumer services companies over the course of COVID-19. Front. Psychol. (2022). [cited 28 Sept 2022]. Retrieved from https://www.frontiersin.org/articles/https://doi.org/10.3389/fpsyg.2022.818845/full
26. Pantano, E., Willems, K.: How Pandemic Crisis Times Affects Consumer Behaviour. Emerald Publishing Limited (2022). ISBN: 978-1-80117-847-1
27. Das, D., Sarkar, A., Debroy, A.: Impact of COVID-19 on changing consumer behaviour: lessons from an emerging economy. Int. J. Consum. Stud. **46**(3) (2022). https://doi.org/10.1111/ijcs.12786
28. Sinclair, L., Moneta, J.: COVID-19 has accelerated digital adoption—the time to transform is now. Futur. Mark. (2020). [cited 28 Sept 2022]. Retrieved from https://www.thinkwithgoogle.com/intl/en-gb/future-of-marketing/digital-transformation/covid-accelerated-digital-adoption/
29. Aronson, G.: Consumer behavior in the Covid recovery: polarizing "moving-on mindsets" within retail. NielsenIQ (2021). [cited 28 Sept 2022]. Retrieved from https://nielseniq.com/global/en/insights/commentary/2021/consumer-behavior-in-the-covid-recovery/
30. Bilková, K., Križan, F., Zeman, M.: Vplyv pandémie COVID-19 na zmeny nákupného správania spotrebiteľov na Slovensku. Výskumná správa. Geografický ústav SAV: Sociologický ústav SAV (2021), p. 13
31. Behúňová, I.: Pandémia urýchľuje zmenu nákupného správania Slovákov. In: Národná Banka Slovenska—Informácie pre médiá. (2021). [cited 29 Sept 2022]. Retrieved from https://nbs.sk/aktuality/pandemia-urychluje-zmenu-nakupneho-spravania-slovakov/
32. MasterCard.: Hogyan változtak az online vásárlási szokások 2020-hoz képest? Fizetési Élmény Riport, p. 23 (2021)
33. PWC.: Consumers respond to waves of disruption. Consum. Mark. (2022). [cited 29 Sept 2022]. Retrieved from https://www.pwc.com/gx/en/industries/consumer-markets/consumer-insights-survey.html
34. Ngaliman, M., Giofani, E.J., Suharto: The effect of tangibles, responsiveness, and reliability on customer satisfaction of delivery services. Int. J. Econ. Manag. Stud. 86–92 (2019)
35. Johnson, E., Karley, J.: Impact of service quality on customer satisfaction. Student Thesis, Master Degree. University of Gävle, Faculty of Education and Business Studies (2018)
36. Akula, S.C.: Impact of COVID 19 on entrepreneurship: a systematic review. Int. J. Ebusiness Egovernment Stud. **13**(1), 1–22 (2021). ISSN: 2146-0744 (Online). https://doi.org/10.34111/ijebeg.202113101
37. Ascarza, E., Ebbes, P., Netzer, O., Danielson, M.: Beyond the target customer: social effects of customer relationship management campaigns. J. Market. Res. **54**(3), 347–363 (2017). https://doi.org/10.1509/jmr.15.0442
38. Reicheld, F.F.: Lead for loyalty. Harv. Bus. Rev. **79**(7), 76–84 (2001)
39. Hoekstra, J.C., Leeflang, P.S.H.: Marketing in the era of COVID-19. Ital. J. Mark. 249–260 (2020). https://doi.org/10.1007/s43039-020-00016-3
40. Koppala, S.: 3 customer acquisition strategies for post-pandemic retail. Retail. Cust. Exp. (2021). Retrieved from https://www.retailcustomerexperience.com/blogs/3-customer-qcquisition-strategies-for-post-pandemic-retail/
41. Jancikova, E., Strazovska, L.: New trends in financing small and medium enterprises in the EU. Actual Probl. Econ. **173**(11), 87–95 (2015)
42. Ďuriš, M., Olvecká, V., Strážovská, Ľ., Sulíková, R.: Influence of the globalization on doing business in Slovakia. In: Proceedings of the 32nd International Business Information Management Association Conference, IBIMA 2018—Vision 2020: Sustainable Economic Development and Application of Innovation Management from Regional expansion to Global Growth, pp. 7310–7318 (2018)
43. Csabay, M., Stehlikova, B.: Firm size distribution and the effects of ownership type. J. Compet. **12**(4), 22–38 (2020)
44. Csabay, M., Vincúrová, Z., Stoch, M., Stehlíková, B.: Enterprise ownership patterns in the least developed districts of Slovakia. Equilibrium. Q. J. Econ. Econ. Policy **16**(4), 807–838 (2021)

45. Katrencik, I., Zatrochova, M.: Financial literacy of technically oriented students in Slovakia: an evaluation of fundamentals of financial literacy. In: EDULEARN22 Proceedings, pp. 574–581 (2022)
46. Urikova, O., Ivanochko, I., Kryvinska, N., Zinterhof, P., Strauss, C.: Managing complex business services in heterogeneous eBusiness ecosystems—aspect-based research assessment. Procedia Comput. Sci. **10**, 128–135 (2012). https://doi.org/10.1016/j.procs.2012.06.020
47. Fedushko, S., Ustyianovych, T., Syerov, Y., Peracek, T.: User-engagement score and SLIs/SLOs/SLAs measurements correlation of eBusiness projects through big data analysis. Appl. Sci. **10**(24), 9112 (2020). https://doi.org/10.3390/app10249112

Advancing Video Search Capabilities: Integrating Feedforward Neural Networks for Efficient Fragment-Based Retrieval

Nataliia Melnykova, Natalya Shakhovska, Petro Pobereiko, and Dariusz Cichoń

Abstract The article focuses on the development of video search technologies. It addresses the challenges in video content analysis and retrieval, especially in the context of rapidly growing video data volumes. The paper presents an innovative system using Deep Convolutional Neural Networks (DCNN) to improve the speed and accuracy of video data processing. This system structures the data processing in several sequential stages, each performed by a separate module, and integrates Feedforward Neural Networks (FFNN) to optimize the search process. The research emphasizes the importance of feature extraction, key frame identification, and abstract vector representation in enhancing video search capabilities.

Keywords Deep convolutional neural networks · Video search · Data processing · Feature extraction · Feedforward neural networks

1 Introduction

In recent years, there has been a rapid development in video content and an increase in its volume, indicating the transformation of this type of visual data into one of the most effective means of information dissemination. These dynamic prompts researchers to develop information systems capable of analyzing visual data to meet

N. Melnykova (✉) · N. Shakhovska · P. Pobereiko
Lviv Polytechnic National University, Lviv, Ukraine
e-mail: melnykovanatalia@gmail.com

N. Shakhovska
e-mail: nataliya.b.shakhovska@lpnu.ua

P. Pobereiko
e-mail: pobereyko.petro26@gmail.com

D. Cichoń
AGH University of Krakow, Krakow, Poland
e-mail: dcichon@agh.edu.pl

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2024

P. Štarchoň et al. (eds.), *Data-Centric Business and Applications*, Lecture Notes on Data Engineering and Communications Technologies 213,
https://doi.org/10.1007/978-3-031-62213-7_9

user needs. Particularly valuable are the developments of automated systems for searching videos by arbitrary fragments. Academic and practical interest in this field is driven by the potential of such systems to improve search mechanisms in the media sphere and their effectiveness in combating the spread of illegal content. The efficiency of video search based on individual fragments becomes particularly relevant in the context of the rapid increase in the volume of digital content. Automated video search systems by fragments are extremely important in protecting intellectual property. They allow for the timely detection and blocking of video copies that violate copyright laws. The implementation of these systems significantly enhances the efficiency of managing large volumes of video data in the media industry, educational institutions, and scientific organizations. Furthermore, the development of these systems significantly impacts research in the field of artificial intelligence, as the improvement of existing and the development of new video search systems by fragments is only possible with the advancement of complex machine learning algorithms and computer vision [1, 2].

Currently, there is a partial mismatch between the low-level data of videos and the requirements of users. The majority of modern video search methods are based on the paradigm of transforming low-level characteristics into higher semantic concepts. This approach necessitates preliminary data processing, and the results of such transformation often prove to be unstable. The task becomes even more complex without considering the specifics of a particular subject area. Additionally, in the modern digital media space, there is an increase in the number of so-called fuzzy duplicates of videos, which consist of fragments with similar, but not identical, content elements. Consequently, searching for the original or similar video material without knowing the exact description or keywords for individual fragments becomes significantly more complicated. One way to solve this problem is to develop new methods and systems for video search based on the analysis of visual content [3].

Analysis of modern research and results in this field indicates that for the identification of videos and to enhance the effectiveness of searching their originals, it is appropriate to refine multi-stage video search systems based on the analysis of visual content [4]. These systems should provide an optimal balance between search speed and accuracy of matching, minimizing errors in the results. One of the main tasks in constructing such systems is the task of extracting image features (frames) to create metadata (representation models) while preserving the essence of the video fragment for subsequent comparison with database data. At this stage, tasks of transformation, extraction, and analysis of image features are addressed using image processing and analysis technology. During this stage, images undergo transformations to modify their geometric or color characteristics for more effective processing. The second task is to create vectors of numerical values that effectively represent the images for further analysis. The third task involves extracting and representing the semantic information of the image. Frame characteristic analysis includes the assessment of color parameters (histograms, moments, correlograms, and Gaussian distribution-based models), as well as texture features independent of hue or saturation that reflect the image's homogeneity (often extracted using Gabor filters) [5]. This is complemented by the analysis of contour and shape characteristics, including

the determination of object shapes extracted based on the contours or areas of these objects [6].

Effective selection and application of these features influence the image model used in analysis algorithms, particularly in object detection and recognition. An important aspect is also the consideration of the operating conditions of the systems for which these algorithms will be implemented. Contemporary trends and results indicate several significant approaches to image representation that are effectively used in machine learning. These approaches and methods, optimal for visual search systems, play a key role in the process of machine learning and software product development.

2 The Material and Methods

In the context of the rapid development of digital media, a key task is the creation of innovative video search systems for the effective analysis of large volumes of video data. This section is dedicated to analyzing contemporary scientific research and technological developments in the field of video search by fragment. Specifically, it examines and analyzes advanced methods and techniques used in leading laboratories and companies, with the aim of their application in creating a proprietary video search system.

Most modern methods of video data analysis for creating effective "hash content" are based on extracting spatial attributes from static images and temporal parameters from videos. An important tool in this process is color histograms, which serve as a powerful mechanism in identifying visually similar content. This is because similar materials often have comparable color statistics, which usually remain even after re-encoding or other types of processing. Hsu and other researchers propose a method of dividing videos into segments according to the content of frames and using local color histograms for each segment [7]. However, there is a significant limitation in using only color histograms: there is a high probability of "conflicts" when analyzing materials with different content but similar color characteristics. Equally effective methods of video data analysis for creating effective "hash content" involve the integration of image hashing methods with video structure analysis. For instance, by determining the boundaries of video materials, key frames can be selected for more detailed analysis. There is also the possibility of reducing long videos to short segments without losing significant information, as confirmed by a number of algorithms [8]. These algorithms can be classified into two main categories: pixel domain approaches and compressed domain approaches. Pixel domain approaches use histograms and edge analysis to detect significant color differences between consecutive frames. In contrast, compressed domain approaches are based on parameters such as direct current values, the number of encoded macroblocks, and motion vectors, allowing for the avoidance of full decryption of encoded video.

In the research titled "Searching surveillance video contents using convolutional neural network" [9], a surveillance video content search system utilizing deep convolutional neural networks (CNNs) was developed [10]. This system is based on the application of the pre-trained VGG-16 model, used for training the dataset. A notable feature of the system is the processing of key video frames using the Sobel edge detector and the Max-pooling method [11], which allows for the removal of redundant data and ensures compactness of information. The VGG-16 model, an integral part of this system, is known as one of the leading deep convolutional neural networks for image classification and includes 16 layers [12], comprising convolutional layers, ReLU (Rectified Linear Unit) activation layers [13], Max-pooling layers, and fully connected layers. The Sobel edge detector effectively extracts key image features, such as edges and contours, aiding in highlighting the structural characteristics of frames. The Max-pooling method reduces the dimensionality of the data while retaining important information, helping to decrease the volume of data for processing and reducing the risk of model overfitting. The ReLU activation function operates on the principle that the input signal is passed unchanged in the case of a positive value and becomes zero in the case of a negative one. Mathematically, this is expressed as $f(x) = max(0, x)$. A major advantage of ReLU is its ability to accelerate the network training process through more efficient gradient descent, especially in comparison to other activation functions such as sigmoid or hyperbolic tangent [10].

Zhuang [14] developed a clustering methodology for identifying key frames, based on grouping similar shots and their subsequent distribution into clusters according to their positioning in the video. Wolfe [15] introduced a method of using optical flow for key frame selection. Wang and others [16] recommend selecting key frames from areas of high compression, using a criterion of high motion intensity, focusing particularly on high motion intensity and its concentration in the central part of the frame. Liu and others [17] proposed an innovative approach based on the "perceived motion energy" model, which enables the identification of key frames based on peak motion energy.

In the research "VEDL: a novel Video Event searching technique using Deep Learning" a three-step approach is presented for efficient event searching in videos using deep learning methods [18]. This approach includes:

1. Key Frame Extraction: In this stage, key frames are selected from the video using the sieve of Eratosthenes method, encompassing both global and local perspectives of frames. The underlying concept of map-reduce significantly reduces the overall processing time of visual data.
2. Event Detection: A pre-trained deep learning model consisting of convolutional neural networks (CNNs) and recurrent neural networks (RNNs) identifies events in key frames [19]. The model is designed for effectively describing events in images.
3. Event Boundary Determination and Index Creation: At this stage, event boundaries are calculated, and an index of various events in the video is created.

The process involves determining the start and end times of events, facilitating efficient video event searching.

The study focuses on key frames and utilizes deep learning, significantly saving time. Comprehensive analysis combining global and local perspectives ensures thorough video analysis. However, there are several drawbacks:

1. Complexity: The deep learning model [20, 21] require significant computational resources.
2. Potential Inaccuracies: Reliance on key frame extraction and model prediction may lead to missed or incorrectly identified events in complex video scenarios.

Wu and others [22] used recording duration as a temporal parameter, applying a fast matching algorithm. Matching was conducted using a suffix array algorithm for efficiency, focusing solely on temporal data. Jalousie and others [23] implemented a method of selecting key frames using radial design vectors and Discrete Cosine Transform (DCT) for hash formation. Zargari and others [24] developed a methodology for extracting compressed domain features in H.264/AVC, using spatial prediction histogram as a descriptor. Overall, researchers believe that methods of summarizing and identifying key frames in videos are most effective only when machine learning is used. They note that thanks to the application of machine learning algorithms, video search systems enable users to more accurately analyze large volumes of video data, identify significant moments, and automatically select important frames. These technologies allow for precise analysis and indexing of large volumes of video data, effectively retrieving and restoring video fragments based on complex queries. The integration of these methods with advanced image processing algorithms and video analysis allows the creation of systems that not only accurately respond to user queries but also provide fast and efficient search solutions, adapting to various formats and types of video content.

3 System Overview

In this work, an innovative video search system using deep convolutional neural networks (DCNN) has been developed, significantly enhancing the speed of processing visual data while maintaining the accuracy of video file search results [25]. In the proposed system, the data processing procedure is structured into several consecutive stages, each executed by a separate module. This architecture (Fig. 1) implements a sequential analysis of video content. The video search process by the system begins with the initiation of loading a video fragment, which is the starting point for its detailed processing. To increase the accuracy of video analysis, the video fragment is divided into individual frames, after which the system processes each frame individually. Then, to ensure data uniformity, each frame is normalized, aiming to standardize the sizes of frames in the video fragment. This process includes reducing the number of pixels in each frame using a bilinear interpolation algorithm,

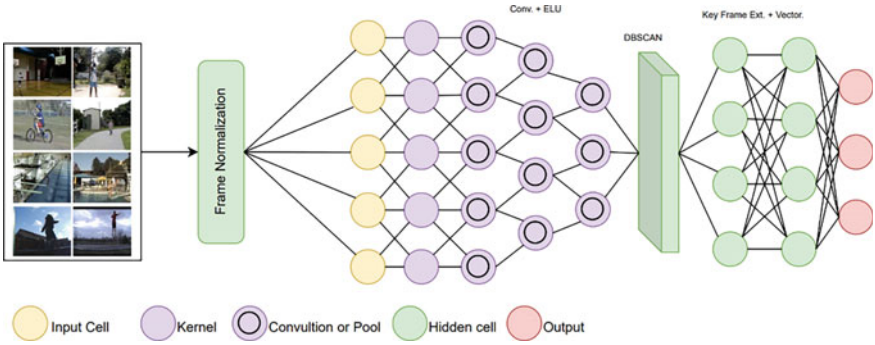


Fig. 1 Schematic representation of the neural network architecture for a video search system by fragments

which employs linear interpolation first in one direction and then in another, to determine new pixel values. Initially, the four closest pixels around the target point in the original image are identified. Then, linear interpolation formulas are applied: first horizontally between the top and bottom pixels, resulting in intermediate outcomes, and then vertically between these intermediate outcomes to obtain the final pixel value. This method ensures a smooth and natural image after resizing, effectively minimizing artifacts and preserving key visual characteristics of the original image.

After the frame normalization process, each frame undergoes a feature extraction procedure implemented by a deep convolutional neural network (DCNN) algorithm. The choice of DCNN for feature extraction is justified by the ability of DCNNs to effectively recognize and analyze visual features at various levels of abstraction [25]. These networks automatically learn to identify significant characteristics, particularly textures, colors, and shapes, which is important for distinguishing different types of scenes or objects in a video. For searching key frames, we have chosen color intensity as the characteristic feature. Let's briefly consider two optimal color spaces: RGB and YUV [26]. If the task involves searching for similar video frames based on their visual content, using the RGB color space may be more appropriate, as it directly represents the primary colors perceived by human vision. This allows for more accurate matching of similar frames based on color similarity. However, searching based on RGB color may require more computation.

The task of our system involves quick searching of similar video frames; in this case, we chose characteristics based on the content of brightness and chromaticity, namely the use of the YUV color space. It allowed us to separate information about brightness and chromaticity and provide a more efficient search. Additionally, we subsampled the chromaticity information to reduce computational demands, using a limited palette of colors and coefficients.

To perform the conversion, the following ratios and formulas were used:

- Y (luminance) is defined as the weighted sum of the RGB values:

$$Y = 0.299R + 0.587G + 0.114B. \tag{1}$$

- U and V (color components) define chrominance relative to gray:

$$U = -0.14713R - 0.28886G + 0.436B. \tag{2}$$

$$V = 0.615R - 0.51499G - 0.10001B. \tag{3}$$

The numbers in the formula for converting RGB to YUV for brightness (Y) stem from the way the human eye perceives light. The human eye is more sensitive to green color, hence the weight for the green channel (G) is the highest. Red (R) is also important, but less sensitive than green, and thus has the second highest weight. The least weight is assigned to the blue channel (B), as the human eye is least sensitive to blue color. These coefficients were determined based on the PAL and NTSC standards, which originated from BT.470 System M and were used in SMPTE RP 177 [27]. They were established to create a Y′UV signal from an RGB source, using weighting values for R, G, and B to obtain a measure of overall brightness or luminance (Y′).

Therefore, in the system, the input data for the DCNN are frames in YUV format. Each frame is represented as a matrix with three channels (Y, U, V), where each channel is a two-dimensional matrix that represents the intensity of the respective component. The first layer of the DCNN contains convolutional layers, using filters with sizes of 5 × 5. This size was chosen for several reasons: more parameters (25 weights) than smaller-sized filters, a larger "receptive field"—meaning they more attentively "look at" a section of the input data, which helps in detecting more global features, and are used for reducing the dimensionality (down sampling) of the image. The result is a new matrix (so-called "feature map") that represents the features detected by the filter. The activation function chosen was the Exponential Linear Unit (ELU) [28]. ELU is an extension of the traditional Rectified Linear Unit (ReLU) activation function, the values of which are determined by the formula:

$$ELU(x) = \left\{ \begin{array}{r} x,\ x > 0 \\ q(e^x - 1),\ x \leq 0 \end{array} \right\}, \tag{4}$$

where a—is a positive constant that determines saturation for negative net inputs.

The main reasons for choosing ELU for our system are:

1. Improved Information Retention: the proposed system requires precise extraction and retention of information about color shades and textural features in video frames. ELU, with its soft saturation property for negative input values, allows for more effective retention of this important information, avoiding its deformation or loss in deep layers of the network.
2. Reducing the Vanishing Gradient Problem: deep neural networks are prone to the problem of vanishing gradients, especially in cases where gradients necessary for training become very small in the lower layers. ELU reduces this problem

due to its non-linear characteristic on negative values, significantly improving the preservation of gradients during training [29].

3. Faster Convergence Speed: the efficient transfer of gradients in ELU contributes to quicker convergence during the network's training. For our system, where large volumes of video data often need to be processed, the ability to quickly learn important features is key to ensuring high performance.
4. Stability and Reliability: compared to other activation functions, such as ReLU, ELU provides more stable and reliable information processing, which is critically important for accurate video analysis.

Collectively, the choice of ELU as the activation function for our CNN, aimed at analyzing YUV video frames, ensures an optimal combination of accuracy, speed, and reliability, which are crucial for the successful execution of our system's tasks. After feature extraction, it was decided to use clustering algorithms for further refinement of key frame selection methodologies [29].

For this purpose, DBSCAN (Density-Based Spatial Clustering of Applications with Noise) [30] was chosen as the optimal algorithm, which is effective for the tasks set [31]. It identifies clusters based on the evaluation of data density and can automatically adapt the number and sizes of data clusters according to the complexity of the processed video data, which is particularly important for analyzing large video streams with a variable number of objects on the screen. Additionally, it allows for the identification of separate noise points that do not belong to any cluster. This is useful for identifying anomalies or deviations in video data that may arise due to errors or noise. Moreover, one of the most significant advantages of DBSCAN is its ability to perform clustering without a predefined number of clusters, thereby ensuring high flexibility and adaptability in processing video data. For the effective application of DBSCAN, it is important to determine the optimal parameters for 'radius' (eps) and 'minimum number of neighbors' (min_samples). These parameters were set based on a series of numerical experiments, the results of which are presented in the following sections of the work. It should be noted that the optimal values of these parameters may vary depending on the characteristics and volumes of the processed data. The process of determining these parameters during experimental analysis was based on the following approach.

The initial phase of the experimental setup for the 'radius' parameter (eps) in the DBSCAN algorithm involved determining a range of its possible values. To do this, we conducted a series of clusterings using different radius values, which varied from smaller to larger, to evaluate the impact of this parameter on clustering results. For each individual radius value, we analyzed the quality of clustering using standardized evaluation metrics. This analysis allowed us to identify dependencies of radius values on the structure of the clusters. Thus, a study was conducted, and subsequently, a separate subsystem was introduced to adjust these values.

For the selected radius value, experiments were conducted with different values of the min_samples parameter. Experimental studies were carried out in the range of min_samples values from the smallest to the largest, evaluating the clustering results

for each min_samples value. In particular, we assessed how the change in min_samples affects the number and size of clusters, as well as the quality of clustering.

Therefore, for the initial data, the radius was set to a value of 0.5, which for us is an average value for video resolution, speed of object changes in frames, the amount of noise in the data, and the overall structure of the video. For min_samples, a value of 25 was chosen because we plan to analyze medium-loaded videos and need high stability and confidence in the detection of clusters during the training process and subsequent automatic adjustment of these values. Setting min_samples = 25 makes the clustering less sensitive to random changes in video data, which can be useful when analyzing average video streams with a moderate level of dynamics. The result of the video data clustering is the formation of groups of video frames, where each formed group reflects a distinct visual similarity among the video frames, taking into account their representation in YUV components.

The next step is the second level of the neural network, which takes groups of frames and for each group of frames looks for the one with the highest weight, thus considering it as the key frame in the group. For each frame in YUV format, we calculate the average brightness value (Y-channel) using the following formula:

$$Avg_Y = \sum Y[i,j]/(height * width), \tag{5}$$

where $Y[i,j]$ is the value in the Y-channel for the area at position (i, j) in the matrix, and (height * width) is the total number of blocks (groups of pixels) in the frame.

The output result of the second level of the network will be a group of three-dimensional matrices, where each matrix represents a key frame with the highest average brightness value in the respective group.

The third level in the neural network will be responsible for transforming the group of key frames, in the form of three-dimensional matrices containing information about brightness (Y), Chroma color (U), and Chroma color (V), into an abstract vector representation. This process is critical for subsequent efficient searching and comparing of video fragments in the database. Each key frame in the output group undergoes intensive processing at this level. Suppose the YUV array has dimensions (H, W, 3), where H is the height of the image, W is the width of the image, and 3 corresponds to the Y, U, and V components.

1. Flattening the array:

Let YUV[i,j] represent a pixel at coordinates (i, j), where i is the row and j is the column. We flatten the three-dimensional array into a two-dimensional array, where each row of the array represents an image pixel, and the Y, U, and V components are located side by side.

For each pixel (i, j), we can create a YUV vector:

$$YUV[i,j] = [Y[i,j], U[i,j], V[i,j]], \tag{6}$$

where $Y[i,j]$ is the brightness of the pixel, $U[i,j]$ is the Chroma U color, and $V[i,j]$ is the Chroma V color.

2. Creating feature vectors:

Now we have a YUV vector for each pixel. We can create a feature vector F[i,j], which represents the pixel in vector form:

$$F[i,j] = [Y[i,j], U[i,j], V[i,j]], \tag{7}$$

where $F[i,j]$ is the feature vector for the pixel (i, j).

After creating feature vectors for all pixels, we can combine them into a flat representation or vector. To do this, we can consider all the F[i,j] vectors as separate rows in a vector matrix. That is, if we have H rows and W columns in the original image, then after flattening, we get a feature vector that has dimensions (H * W, 3), where 3 is the number of YUV components.

We can represent this in mathematical form:

$$F_flat = [F[1,1], F[1,2], ..., F[1, W], F[2,1], F[2,2], ..., F[H, W]], \tag{8}$$

where F_flat is the flattened representation of feature vectors.

Thus, we obtained a flat vector representation for the entire YUV image, allowing further processing and analysis for use in the video fragment search system.

After generating keyframe vectors at the third level of the neural network, there arises a need to search for similar vectors in a large video dataset. To achieve this, we use the FAISS library, utilizing YUV-based vectors to calculate the distance between vectors.

Initially, an index is created that allows FAISS to perform efficient vector searches in the video database [32]. This index is based on vectors stored in the database, using the distance between them calculated based on YUV information.

After creating the index, the neural network initiates a search for corresponding vectors in the database, sending queries with keyframe vectors at the third level of the neural network. The result is a set of the nearest neighbors for each of these vectors.

Next, the obtained results are ranked based on the distance between the vectors, calculated using YUV information and other relevant indicators. This stage determines the relevance and significance of each found option. After receiving the ranking results obtained at the third level of the neural network, the top five most significant options are identified. These options represent key frames or vectors that best meet the criteria of similarity and relevance.

Then, a search for these three options is conducted in our video dataset. All videos containing these key frames or vectors are analyzed, and the number of matches for each video with these options is determined. The original videos with the most matches with the three selected options are chosen as the most relevant results. This procedure allows highlighting videos that best correspond to the input query based on the analysis of similarity and relevance of keyframe vectors. Thus, it ensures the selection and output of the most similar output videos from the database based on the distance between vectors, formed based on YUV information and the number of matches with keyframe vectors.

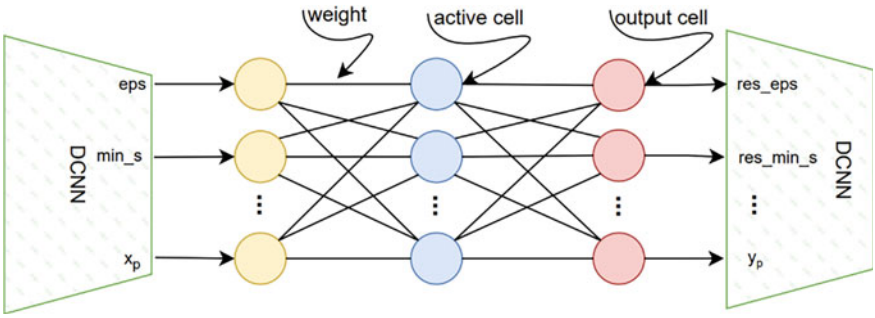


Fig. 2 Schematic representation of neural network architecture for search engine optimization

To optimize the video search process using DCNN and enhance the speed and effectiveness of searching for videos by arbitrary fragments, it was decided to utilize a subsystem based on the Feed-forward Neural Network (FFNN) [33]. The FFNN subsystem analyzes the output data and performance metrics of the DCNN, using machine learning algorithms and mathematical models to adjust its hyperparameters. In this role, the Feed-forward Neural Network functions as an analytical tool, utilizing a dataset about the performance of the DCNN (such as accuracy, losses, processing time) to determine optimal settings. The FFNN will have several layers: an input layer that receives the DCNN metrics, a hidden layer for processing these data, and an output layer that generates recommendations on hyperparameters (Fig. 2).

A neuron in a Feedforward Neural Network (FFNN) uses a bias and the ReLU (Rectified Linear Unit) activation function [34]. It operates through several key mathematical operations. Here is a detailed description of this process:

Linear Combination—each neuron receives input signals $x_1, x_2 \ldots, x_n$, where n—is the number of inputs. Each input signal is multiplied by a corresponding weight $w_1, w_2 \ldots, w_n$. The sum of these weighted inputs is determined by the formula:

$$z = w_1x_1 + w_2x_2 + \cdots + w_nx_n + b, \tag{9}$$

where b—is the bias, which is added to the sum of the weighted inputs.

The bias allows the neuron to shift the activation function to the left or right on the graph, providing additional flexibility to the network. After calculating the linear combination, the result z is fed to the activation function. In the case of ReLU, the function is defined as:

$$ReLU(z) = max(0, z) \tag{10}$$

This means that if z is positive, the function returns the value of z, and if z is negative, the function returns 0 (Fig. 3). Thus, the output signal of the neuron y will be:

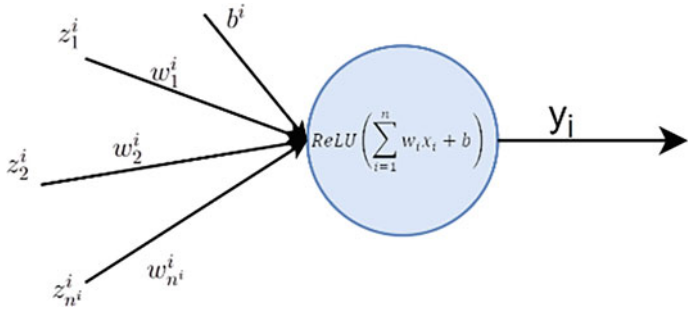


Fig. 3 FFNN neuron with activation function

$$y = ReLU(z) = ReLU\left(\sum_{i=1}^{n} w_i x_i + b\right), \tag{11}$$

where:

z—is a linear combination of inputs;
w_i—is the weight associated with the i-th input;
x_i—is the i-th input signal;
n—is the total number of inputs;
b—is the bias (offset).
Input Data for FFNN:

1. System Runtime: The duration of each operation in the system.
2. DBScan Parameters: eps (neighborhood radius) and min_samples (minimum number of points to form a cluster).
3. Additional Metrics: Include clustering accuracy, the number of detected clusters, and the percentage of noise. For accuracy, the Adjusted Rand Index (ARI) is used—a measure of similarity between two clusterings that considers randomness. It ranges from -1 to 1, where 1 indicates perfect clustering (in experiments with the same fragment). For calculating noise points in the DBScan algorithm, points that do not belong to any cluster are considered noise. The percentage of noise is calculated as the ratio of the number of noisy points to the total number of points.

FNN will analyze the impact of changes in the values of eps and min_samples on the effectiveness of clustering. It will learn to predict optimal values for these parameters depending on the input data (the size and complexity of the dataset).

With the introduction of the DCNN subsystem, it can dynamically adjust DBScan parameters based on current accuracy and noise analysis. Regular monitoring of these metrics helps in identifying areas for improvement of algorithms and data processing processes. The use of these methods will not only allow evaluating the effectiveness of clustering in your system but also provide information for its optimization, thereby enhancing the quality and performance of data processing.

4 Results

In the study, a dataset was used for training and evaluating the effectiveness of the proposed video search system based on arbitrary fragments. The UCF-101 dataset contains 13,320 video files, divided into 101 non-overlapping categories [35]. Each file has a resolution of 240 × 360 pixels and a fixed frame rate of 25 frames per second (FPS). The duration of the videos varies from 1.06 s to 71.04 s. These data are used for training and validating the video search system for arbitrary fragments. They allow for the assessment of the effectiveness of the developed system in searching video fragments. For training and validation of the system, a method of "deferred" division of training data into subgroups is recommended, and a test set should be used to determine the accuracy of its testing. The data were divided into sets for training and testing, consisting of 70% training data and 30% testing data.

For training the system and populating it with data, video files were converted into the YUV format. In the system, the search layer was modified to enable the storage of a file with key frames and vectors linked to the corresponding video. Video fragments with a maximum duration of 20 s were selected for identification, with some of these fragments not included in the test base of originals. A high level of performance was achieved through the representation of video material in the form of a compact, minimized set of characteristics. Additionally, to enhance data processing efficiency, a method of clustering with vector space indexing was applied. During training and searching with FFNN, we monitored the output parameters of the network, forming a graph showing the relationship between search time and the number of videos in the database (Fig. 4). This allows for an assessment of the speed of data normalization and processing.

Within the framework of the conducted research, an assessment of the effectiveness of video data clustering was carried out, with a particular focus on the accuracy of

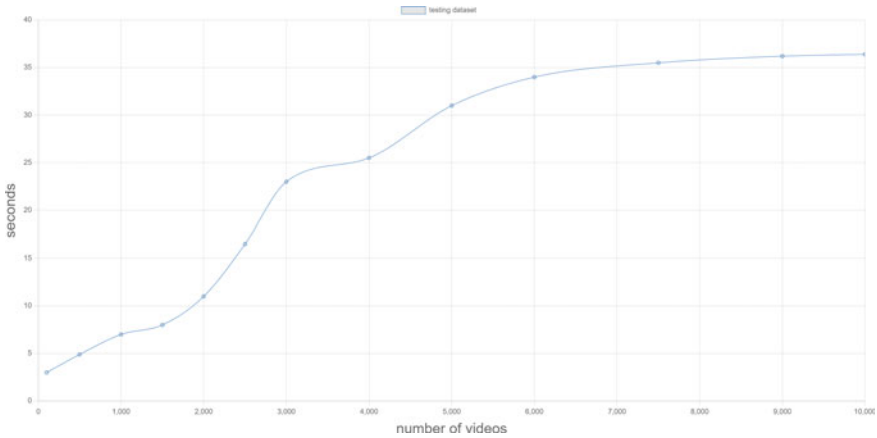


Fig. 4 Dependence of search speed on the number of videos in the system

key frame identification. For this purpose, video fragments with a maximum duration of up to 20 s were used, some of which were not included in the original database.

The main parameters for the DBSCAN (Density-Based Spatial Clustering of Applications with Noise) clustering algorithm included the radius (epsilon) and the minimum number of samples (min_samples). The radius varied from 0.3 to 0.6, while min_samples remained unchanged, as the number of frames in the dataset was constant.

As a result of the study, the following accuracy metrics were obtained: for the training data set, the accuracy was 93.36%, and for the test set, it was 86.36%. For comparison, in the context of an architecture without the use of the FFNN (Feedforward Neural Network) subsystem, the accuracy for the training set was 74.36%, and for the test set, it was 66.04%. These results underscore the importance of the additional subsystem in the process of optimizing clustering parameters. It is important to note that the absence of this subsystem leads to a significant discrepancy in accuracy, indicating a high sensitivity of clustering parameters to the final representation of frames. Thus, the integration of FFNN as part of the system provides a significant improvement in overall performance and accuracy in identifying key frames in the video stream.

The final results of this study point to the significant importance of the architectural innovation that was proposed and implemented, and its impact on the effectiveness of key frame detection in the video stream.

5 Discussion

The study focuses on improving video search capabilities, particularly through the use of Feed-Forward Neural Networks (FFNN) and Deep Convolutional Neural Networks (DCNN). The research highlights limitations of current video search methods, especially in processing large volumes of video data and the complexity of video content. These challenges necessitate advancements in algorithms for assessment and prediction. The study emphasizes the importance of feature extraction, key frame identification, and abstract vector representation as critical for enhancing video search capabilities. It discusses the difficulties in transforming low-level video data into high-level semantic concepts and the need for preprocessing these data. A proposed multi-stage video search system balances search speed and accuracy, minimizing errors in results. This includes complex machine learning algorithms and computer vision methods. The system uses the YUV color space for effective feature representation and employs the DBSCAN clustering algorithm for key frame selection. Deep learning models are crucial for recognizing and analyzing visual features at various levels of abstraction. Optimization and Challenges: The system architecture is designed to optimize the video search process and adapt to different formats and types of video content. However, the complexity of deep learning models and potential inaccuracies in key frame selection and event prediction are noted as challenges. To address complexity, more efficient deep learning algorithms requiring

fewer computational resources could be considered. Cloud computing might also be used to provide the necessary computational power without the need for expensive hardware investments. Optimizing Deep Convolutional Neural Networks (DCNNs) through the implementation of asynchronous operations is a progressive approach in computational efficiency. Asynchronous operations in DCNNs will enable simultaneous processing of multiple layers or segments of the network. While one part of the network is being processed, other parts can be loaded or pre-processed, effectively utilizing idle computational resources.

Future Implications: The research indicates that integrating advanced image processing algorithms and video analysis methods with machine learning could lead to systems that not only accurately respond to user queries but also provide quick and efficient search solutions. The next steps for improving and optimizing the system based on the results are Reinforcement Learning (RL). RL involves several key steps for effective implementation within a system. Initially, it's crucial to define the 'reward' mechanism—this could be, for example, positive user feedback on search results. Subsequently, an appropriate RL model needs to be selected, which could range from Q-Learning and Deep Q-Networks (DQN) to Policy Gradients, depending on the specific requirements of the task. The chosen RL model should then be seamlessly integrated into the system to ensure it can receive feedback from users and adjust its parameters accordingly. Finally, thorough testing and optimization of the algorithm are necessary to ensure that it efficiently adapts the system to meet user needs. And one more important step for the future it's fine-tuning of neural network models represents a sophisticated approach in enhancing the performance of video search systems for specific genres or types of content. This process involves the initial training of a model on a broad dataset to establish a general understanding of video features, followed by additional training phases on datasets comprising specific genres or styles. Such a targeted approach ensures that the model becomes more adept at recognizing and categorizing nuances unique to these specific categories. This fine-tuning not only refines the model's accuracy in identifying genre-specific elements but also improves its overall efficacy in handling diverse video content. By continuously adapting to more specialized data, the model becomes increasingly efficient in discerning subtle characteristics, leading to more precise and relevant search results.

6 Conclusions

Based on the analysis of literary sources, it has been found that modern technologies for video search by fragments require improvement. The results of their practical implementation in most cases are unstable. In particular, significant difficulties arise in searching for the original video material by individual fragments in cases where there is no knowledge or keywords about these fragments. It has been established that one of the ways to solve this problem is to search for videos based on the analysis of visual content. Using the architecture of Deep Convolutional Neural

Networks (DCNN) and Feedforward Neural Networks (FFNN), a new system for searching video materials has been developed with a structured approach to data through sequential stages and modular components. To justify the effectiveness of the developed system, corresponding experimental studies have been conducted, and based on the obtained results, the practicality and applicability of the proposed system in real scenarios have been confirmed. The proposed system demonstrates high results in the accuracy of visual content identification.

References

1. Indriyani, Dewanti, P.: Analysis of the effect of social media on the marketing process in a store or business entity 'social media store. Budapest Int. Res. Critics Inst. J. **4**(4), 9804–9814 (2021)
2. Bridges, A.W.: Skills, content knowledge, and tools needed in a 21st century university-level graphic design program. Visual Commun. J. **52**(2), 1–12 (2016)
3. Saragih, M., Harahap, A.: The challenges of print media Journalism in the digital Era. Budapest Int. Res. Critics Inst. BIRCI J. **3**(1), 540–548 (2020)
4. Fedushko, S., Mastykash, O., Syerov, Y., Shilinh, A.: Model of search and analysis of heterogeneous user data to improve the web projects functioning. Lecture Notes on Data Engineering and Communications Technologies, vol. 83, pp 56–74. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-80472-5_6
5. Konrad, J., Wang, M., Ishwar, P., Wu, C., Mukherjee, D.: LearningBased, automatic 2D-to-3D image and video conversion. Trans. Image Process. **22**(9), 3485–3496 (2013)
6. Gong, B., Chao, W.-L., Grauman, K., Sha, F.: Diverse sequential subset selection for supervised video summarization. In: Advances in Neural Information Processing Systems, pp. 2069–2077 (2014)
7. Zhang, H.J., Wu, J., Zhong, D., Smoliar, S.W.: An integrated system for content-based video retrieval and browsing. Pattern Recognit. **30**(4), 643–658 (1997)
8. Cotsaces, C., Nikolaidis, N., Pitas, I.: Shot detection and condensed representation—a review. IEEE Signal Process. Mag. **23**, 28–37 (2006)
9. Mohammad, D., Aljarrah, I., Jarrah, M.: Searching surveillance video contents using convolutional neural network. IJECE **11**(2), 1656–1665 (2021)
10. Varshni, D., Thakral, K., Agarwal, L., Nijhawan, R., Mittal, A.: Pneumonia detection using CNN based feature extraction. 2019 IEEE International Conference on Electrical Computer and Communication Technologies (ICECCT), pp. 1–7 (2019)
11. Huang, G., Liu, Z., Maaten, L.V.D., Weinberger, K.Q.: Densely connected convolutional networks. CVPR, pp. 2261–2269 (2017)
12. Shao, L., Zhu, F., Li, X.: Transfer learning for visual categorization: a survey. IEEE Trans. Neural Netw. Learn. Syst. **26**, 1019–1034 (2014)
13. Naveen, P., Diwan, B.: Relative analysis of ML algorithm QDA LR and SVM for credit card fraud detection dataset. 2020 Fourth International Conference on I-SMAC (IoT in Social Mobile Analytics and Cloud) (I-SMAC), pp. 976–981 (2020)
14. Zhuang, Y., Rui, Y., Huang, T.S., Mehrotra, S.: Adaptive key frame extracting using unsupervised clustering. Proceedings of IEEE Int Conf on Image Processing, pp. 866–870 (1998)
15. Wolf: Key frame selection by motion analysis. IEEE International Conference on Acoustics, Speech and Signal Processing, pp. 1228–1231 (1996)
16. Wang, T., Wu, Y., Chen, L.: An approach to video key-frame extraction based on rough set. Multimedia and Ubiquitous Engineering, 2007. MUE '07. International Conference on, pp. 590–596 (2007)

17. Liu, T., Zhang, H.-J., Qi, F.: A novel video key-frame-extraction algorithm based on perceived motion energy mode. IEEE Trans. Circuits Syst. Video Technol. **13**, 1006–1013 (2003)
18. Solanki, A., Bamrara, R., Kumar, K., Singh, N.: VEDL: a novel video event searching technique using deep learning. In book: Soft Computing: Theories and Applications, pp.905–914 (2020)
19. Liu, Z., Zhang, Y., Li, Y., Chaomurilige. Key news event detection and event context using graphic convolution, clustering, and summarizing methods. Appl. Sci. 13, 5510 (2023). https://doi.org/10.3390/app13095510
20. Indhumathi, J., Balasubramanian, M., Balasaigayathri, B.: Real-time video based human suspicious activity recognition with transfer learning for deep learning. Int. J. Image Graph. Signal Process. **15**(1), 47–62 (2023). https://doi.org/10.5815/ijigsp.2023.01.05
21. Yelmati, S., Rao, J.: Online signature verification using fully connected deep neural networks. Int. J. Eng. Manuf. **11**(5), 41–47 (2021). https://doi.org/10.5815/ijem.2021.05.04
22. Wu, P.-H., Thaipanich, T., Jay Kuo, C.-C.: A suffix array approach to video copy detection in video sharing social networks. In: IEEE International Conference on Acoustics, Speech, and Signal Processing, Taipei, Taiwan (2009)
23. De Roover, C., De Vleeschouwer, C., Lefebvre, F., Macq, B.: Robust video hashing based on radial projections of key frames. IEEE Trans. Signal Process. (2005)
24. Zargari, F., Mehrabi, M., Ghanbari, M.: Compressed domain texture based visual information retrieval method for I-frame coded pictures. IEEE Trans. Consum. Electron. **56**, 728–736 (2010)
25. Li, D., Wang, R., Xie, C., Liu, L., Zhang, J., Li, R., Wang, F., Zhou, M., Liu, W.: A recognition method for rice plant diseases and pests video detection based on deep convolutional neural network. Sensors **20**, 578 (2020). https://doi.org/10.3390/s20030578
26. Liu, Z.G., Zhang, X.Y., Wu, C.C.: A flame detection algorithm based on bag-of-features in the YUV color space. In: Proceedings on International Conference on Intelligent Computing and Internet of Things, Harbin, pp. 64–67 (2015)
27. Shree, D., Kant, C.: Building efficient neural networks for brain tumor detection. J. Positive School Psychol. **6**(11) (2022)
28. Qiumei, Z., Dan, T., Fenghua, W.: Improved convolutional neural network based on fast exponentially linear unit activation function. IEEE Access **7**, 151359–151367 (2019)
29. Li, L., Doroslovački, M., Loew, M.H.: Approximating the gradient of cross-entropy loss function. IEEE Access **8**, 111626–111635 (2020)
30. Maithri, C., handramouli, C.H.: Parallel DBSCAN clustering algorithm using hadoop map-reduce framework for spatial data. Int. J. Inf. Technol. Comput. Sci. (IJITCS) **14**(6), 1–12 (2022). https://doi.org/10.5815/ijitcs.2022.06.01
31. Ohadi, N., Kamandi, A., Shabankhah, M., Fatemi, S., Hosseini, S., Mahmoudi, A.: SW-DBSCAN: a grid-based DBSCAN algorithm for large datasets. 6th International Conference on Web Research, pp. 139–145 (2020). https://doi.org/10.1109/ICWR49608.2020.9122313
32. André, F., Kermarrec, A.-M., Le Scouarnec, N.: Quicker ADC: unlocking the hidden potential of product quantization with SIMD. IEEE Trans. Pattern Anal. Mach. Intell. **43**(5), 1666–1677 (2021). https://doi.org/10.1109/TPAMI.2019.2952606
33. Kwon, T.: Average data rate analysis for hierachical cell structure under nakagami-m fading channel with a two-layer feed-forward neural network. 2019 International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob), Barcelona, Spain, pp. 1–4 (2019). https://doi.org/10.1109/WiMOB.2019.8923280
34. Medus, L.D., Iakymchuk, T., Frances-Villora, J.V., Bataller-Mompeán, M., Rosado-Muñoz, A.: A novel systolic parallel hardware architecture for the FPGA acceleration of feedforward neural networks. IEEE Access **7**, 76084–76103 (2019). https://doi.org/10.1109/ACCESS.2019.2920885
35. Luo, X., Ye, O., Zhou, B.: An modified video stream classification method which fuses three-dimensional convolutional neural network. 2019 International Conference on Machine Learning, Big Data and Business Intelligence (MLBDBI), Taiyuan, China, pp. 105–108 (2019). https://doi.org/10.1109/MLBDBI48998.2019.00026

Technologies for Electronic Document Management in the Enterprise

Mykhaylo Pasichnyk, Hryhoriy Savchuk, Sana Strelbytska, Lesya Tkach, Volodymyr Patrytskyi, and Yurii Palekha

Abstract The reasons for the development of electronic document management as a scientific direction of document management are investigated. The characteristic of modern scientific research is provided. The processes of formation of the complex science of informatics, development of electronic computing equipment at the enterprise, implementation of automated control systems, information technologies, and signs of classification of electronic documents are analyzed. The introduction and expansion of modern information technologies open up opportunities for a qualitatively new organization of management communication and working processes with documents and information. In this regard, there is an increasing need to develop and apply new conceptual approaches in practice. Electronic document management should be viewed as a qualitatively new systemic phenomenon associated not only with technical, technological, documentary, and legal components but also with the development of the social and economic management system.

Keywords Electronic document management · Electronic document · Informatics · office processes · Archival affairs · Information carriers · Automated systems · Documentary science · Information technologies

M. Pasichnyk (✉) · H. Savchuk · S. Strelbytska · L. Tkach · V. Patrytskyi
Department of Information, Library, Archival Affairs and Foreign Languages, Ukrainian Academy of Printing, Pid Goloskom, 19, Lviv 79020, Ukraine
e-mail: ms.pasichnyk@ukr.net

S. Strelbytska
e-mail: sanazhuk@ukr.net

Y. Palekha
Department of Information and Analytical Activities and Information Security, National Transport University, M. Omelianovycha-Pavlenka, 1, Kyiv 01010, Ukraine
e-mail: paleha_yu@ukr.net

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2024

P. Štarchoň et al. (eds.), *Data-Centric Business and Applications*, Lecture Notes on Data Engineering and Communications Technologies 213,
https://doi.org/10.1007/978-3-031-62213-7_10

1 Introduction

1. Structure of information technologies in office work.

A contemporary information procedure in office work involves the ability to use various types of information technology in a comprehensive manner, including modern computers, streamlining the technological stages of documentary support for management processes, and improving document management. This, accordingly, requires:

(1) solving the problem of creating uniform rules for organizing office work in institutions;
(2) development of standard guidelines for drafting, executing, and approving official documents;
(3) creation of a certain system of control over the execution of official documents [1].

Information technology in office management [1] is a set of principles and rules that establish uniform requirements for documenting the activities of an institution and organizing work with documents. The main tasks of using information technology in office management are to develop theoretical knowledge, practical skills, and abilities in paper and electronic document processing.

The term "information technology" is considered as:

– a systematically organized sequence of actions performed on information using automation tools and methods;
– is a process that covers a set of methods of collecting, storing, processing, and transmitting information based on the use of computer technology;
– a process that uses a set of tools and methods for collecting, processing and transmitting data to obtain new quality information about the state of an object, process or phenomenon;
– utilizing computers and software to store, transform, protect, process, transmit and receive information, etc. [2, 3].

Information technology is a process consisting of the sequential performance of certain actions in achieving the set goal and performing tasks, i.e. a process consisting of clearly regulated rules for performing actions, stages of different levels of complexity over data [2].

Information technology tools are hardware, software and organizational support integrated in the process of collecting, storing, transforming, protecting, processing, transmitting and receiving information for decision-making.

Hardware includes main devices (computers) and auxiliary devices (printer, scanner, multimedia devices, etc.).

Software—operating systems, network and application programs (text, accounting, tax, HR, etc.), as well as a set of hardware programs (drivers, antivirus programs, etc.).

Organisational support is a set of data presented in a certain form for computer processing.

Information technology is based on the use of information and computer software and consists of various stages and actions.

Information technologies are used to implement the following stages of information processing: collection and registration of information; machine coding of information; storage of information; processing of information using modern computing methods of mathematical modelling, statistical and other methods; provision of information to customers; analysis of the information received, etc.

Classification of information technologies

The choice of the type of information technology for its use in office work depends on the classification criterion. The criterion may be a set of features that influence the choice of a particular information technology. The following classification features of information technologies are most often distinguished.

Information technologies are classified by characteristics:

(1) purpose of use;
(2) user interface;
(3) a way of organising networking;
(4) the principle of construction;
(5) the degree of coverage of management tasks;
(6) participation of technical means in a dialogue with the user;
(7) method of managing production technology;
(8) type of information processed.

The structure of information technology in office management.

The organisation of procedure with documents based on modern information technologies in office work is based on the use of a modern document management [4, 5] and workflow automation system (DMS) as a set of information technologies focused on the joint and coordinated use of electronic methods of collecting, processing, storing and transmitting information in the form of texts, graphs, tables, etc.

Information technology is a set of methods, production processes, and software and hardware tools integrated into a technological chain that ensures the collection, processing, storage, distribution, and display of information in order to reduce the labour intensity of the processes of using an information resource, as well as to increase their reliability and efficiency [6].

Information technology in office management is a list of technological processes (collection, transmission, processing, storage and presentation of information) that can be viewed as a generalisation of the relevant purposeful changes in the properties of certain data. From the point of view of computer science, office workflows look like this:

Data aggregation is the transformation of a set of data that changes their concentration property, i.e. the process when information coming from different sources on a certain range of issues is collected in one document.

Data transfer is a transformation of a set of data that changes its spatial coordinates, which are considered as a relevant property.

Data processing is the transformation of a set of data, which changes one or another of their qualitative properties, which is necessary for the preparation of a specific document.

Data preservation is the transformation of a set of data for which the time coordinates (from the past to the future) are changed, which are considered as a certain property of the data.

Data presentation is the transformation of a set of data, which changes the type of information—the form of documentary storage or the results of its processing—into a form convenient for use in solving a specific task.

Automated workflow technologies implement the following functional tasks:

- entering documents for further processing and execution;
- registration and accounting of incoming, outgoing and internal documents;
- distribution of documents by executors with the assignment of deadlines in accordance with the relevant regulations;
- control over the execution of documents with the issuance of reminders to executors;
- search for documents upon request;
- maintaining operational and archival document storage funds;
- search for archival information on request;
- generating statistical data and compiling summary documents;
- preparation of certificates to the management on the status of documents execution;
- exchange of documents (external and internal).

Organisations and enterprises use the following CADDs:

1. Document image processing system. It is designed to input, process, store and search graphic images of paper documents.

Main functions:

- scanning documents [7];
- recording to the server;
- classification of documents;
- Transferring images to a workstation;
- search for images by individual elements;
- mailing and printing.

2. Optical character recognition system—for converting paper documents into electronic form as a text file.

Main functions:

– scanning;
– text recognition [8];
– -formatting to a text file.

3. Document management system [9]—to automate the storage, retrieval and management of electronic documents in various formats.

Modern document management systems make it possible:

– index documents;
– conduct full-text keyword searches;
– organise access to the document regardless of the storage location;
– manage the configuration of documents with the establishment of relationships between individual structural components;
– ensure data protection;
– organise access to a document regardless of its storage location;
– manage documents using key components (section names), implement multi-level data protection that allows access to the document only to certain users or sets limited access, for example, "scan only";
– administer accounting and archiving, organise the issuance and return of documents, and monitor existing versions and their distribution.

4. Workgroup software is designed for organisations whose employees, by the nature of their work, need to constantly exchange documents with the tasks of saving, viewing and sharing. The main functions of such groupware can be:

– -e-mail;
– support for video conferencing;
– image management;
– sharing documents;
– routing;
– calendar planning.

The introduction of information technologies should be expressed in the selection and implementation of transformation methods, i.e. the introduction of a certain system of tools and methods of their use. In this respect, the implementation of a particular information technology in office management should presuppose the presence of:

(1) appropriate technical means that ensure the conversion of a paper document into its electronic version;
(2) systems of technological complex management tools (for computing equipment, this means the availability of software tools);
(3) means of organisational and methodological support that combine the implementation of all actions of technical means and personnel into a single technological chain in accordance with the purpose of a specific information process within the documentation of a specific function of management activity [1].

To this end, automated management information systems (AMIS) have been created and are operating on the basis of sectoral automated computer information systems (ACIS), which also perform record keeping functions. The functions of automated control over the execution of documents may be assigned to automated document execution control systems, and the functions of registration, search and storage of documents may be assigned to automated information retrieval systems.

The subsystems that can be used in a unified document management system include: document image processing systems, optical character recognition systems, document management systems and workgroup software [1].

Workflow automation systems are designed to create application systems for collective document processing in the course of performing specific business processes [10]. Document flows in an organisation must be adapted to the business processes that already exist and the rules of their interaction. A strategic challenge for an organisation is the problem of choosing a comprehensive automated document management system that is capable of creating, storing, searching, editing and sending documents. The problem here is that only a few applications in this category approach the level at which all these functions are provided simultaneously.

An ACS can be considered complete if it is able to perform key functions, the most important of which are:

- providing the ability to index and search for documents;
- control the status of work with a document that can be located in any part of the organisation's network;

Quick location determination when needed;

the ability to group documents (combine texts, graphs, tables into one file), forming a certain complex document [1, 11].

Complex document management software should have more features than simple document production systems. Users need tools to create various document types and, therefore, a document management system designed to work with different file types.

"Boxed" software is a multifunctional product with well-developed reference documentation supported by the developer. These packages are designed, as a rule, for the "average" user and do not consider the specifics of a particular institution.

Customised software is a complex, bespoke application with a long, irregular development and implementation cycle. They require significant funding but at the same time, take into account the specifics of a particular enterprise or organization.

Complex generalized products are mass-produced software products that require installation, implementation, maintenance, and technical support. These include accounting software and software for organising and automating specialised office work.

The key factors in evaluating a particular integrated document management system should be:

- ease of exploitation and management;
- cost per user;

- technical support and staff training;
- support for several types of clients;
- compliance with standards for managing complex documents.

Here is the structure of information technologies in office work in the form of a table proposed by Palekha [1, p. 113] (Table 1).

The basis for the functioning of almost all office automation and document management systems (both Western and domestic) is server-based technology, which allows simultaneous creation, analysis, redistribution of information [12], and its quick viewing and search.

Information technologies within the client–server system use the Internet/intranet system, where the intranet is an internal corporate network of an organisation that operates according to Internet standards. This allows for communication between users from any location on the corporate network or with remote users in the workflow and document management system via the Internet.

These software systems are positioned according to the following list [13]:

(1) specialised systems for automating office work and document management (Delo 8.0, Lan Docs);
(2) document flow automation systems that provide for the arbitrary exchange of documents and information (Office Media, Escado);
(3) workflow management systems that allow automating complex multi-step algorithms for working with documents in corporations (Optima Works, Links Works, Staffware);
(4) collective document processing systems aimed at automating the work of a small team and supporting the joint use of information by a group of users (Group Wire and Lotus Notes ("LotusIMB");
(5) electronic document arrays intended for storing documents in electronic form and searching them (Docs Open, Euphrates).

Table 1 Structure of information technology in office management

Means	Subsystems	Software packages	Types of work
Conversion from paper form in electronic	Image processing documents	Boxed	Creation documents
Management technological processes	Optical recognition characters	To order	Document management (document management)
Organisational and methodological procedure	Management documentation	Generalised	Sending documents (e-mail)
	Software provisioning working groups		Group work with documents (groupware)
			Workflow management (workflow)

The modern market of office automation and electronic document management systems offers several solutions for electronic document management [14], including domestic products Megapolis.DocNet and Deals by InBase and Intecracy Deals, which are part of the Intecracy Group consortium [15].

Megapolis.DocNet—is a solution designed for internal document management. The system's functionality allows you to coordinate documents and set tasks at several levels of the organisational structure. An offline mode is available. A mobile app for iOS and Android keeps users up to date with the latest developments.

Solutions Deals solution is designed to work with external contractors. This progressive online service allows you to approve and sign documents in just a few minutes. This solution also features the ability to work with Mobile ID.

All documents signed in Megapolis.DocNet and Deals using an electronic digital signature [16, 17] have the same legal force as those signed manually.

2. Document management systems

The introduction and widespread use of modern information technologies are creating opportunities for a qualitatively new organisation of management communication and processes of working with documents and information. In this regard, there is a growing need to develop and apply new conceptual approaches in practice. Electronic document management should be viewed as a qualitatively new systemic phenomenon associated not only with technical, technological, documentary and legal components, but also with the development of the socio-economic management system.

For any enterprise or organisation, the issues of optimising document flow and controlling information processing are of key importance. The effectiveness of enterprise and organisational management depends to a large extent on the correct solution of the tasks of prompt and high-quality generation of electronic documents, control of their execution, as well as a well-thought-out organisation of their storage, retrieval and use. The need for effective management of electronic documents led to the creation of electronic document management systems (EDMS).

Working with electronic documents includes the creation of documents, their processing, transmission, storage, and output of information circulating in an organisation or enterprise using computer networks.

Electronic document management is the organisation of the movement of documents between organisational units, user groups or individual users. At the same time, the movement of documents is not their physical movement, but the transfer of rights to use them with notification of specific users and control over their implementation.

International Data Corporation (IDC) defines EDMS (Electronic Document Management Systems) as follows: "An EDMS provides the process of creating, managing access to, and distributing large volumes of documents over computer networks, and provides control over document flows in creation. The general capabilities of EDMS include document creation, access control, data conversion and data security" [18].

The main purpose of a DMS is to organise the storage of electronic documents and work with them (including their search by both attributes and content) [19–21].

The EDMS should automatically track changes to documents, deadlines for document execution, document movement, and control all versions and sub-version of documents. A comprehensive EDMS should cover the entire document management cycle of an enterprise or organization—from defining a task to create a document to writing it off to the archive, and provide centralised storage of documents in any format. They should provide flexible document management both by clearly defining the routes of movement and by free routing of documents.

The Concept of Document Management

Although the concepts of "office work" and "management documentation" are close, "management documentation" covers a wider range of issues, including work with various types of management documentation in the context of automation. It should be noted that today the concepts of "office work" and "documentary management support" are actively used as synonyms [1].

The efficiency and quality of decisions made, the effectiveness of their implementation and the organisation's overall performance1 depend on how document management is organised. Traditionally, the area of activity related to the organisation of work with documents in management is called office management. The term "documentary management support" (DMS) [22] appeared in the scientific, educational, and methodological literature in the late 1970s, when work was actively underway to create automated management systems and by analogy with other terms of an automated management system: "software", "information support", "mathematical support", it was named as such. The term "DZU" was used when it came to computer technologies in document management, it emphasised the information and technical component of document management. And the term "office management" was used mainly when it came to the organisational side of working with documents.

The term "document management" is quite closely related to the concept of "documentary management support". According to M.V. Larin, who made the most significant contribution to the development of this issue in Russian documentary studies, documentary management support is "…a term that characterises the transitional stage from traditional record keeping to document management" [5]. In many works of the scientist, various aspects and forms of work with documents in their historical development are studied and the modern content of documentation management activities is substantiated.

In modern conditions, scientists consider document management as a specialised management function that should cover the entire range of issues related to the creation, circulation, storage and destruction of documents generated and circulated in the management system. In our opinion, it is important to consider this function not only at the level of a single organisation, but also on the scale of various management systems.

It should be noted that along with the concept of "records management", the term "document management" is also used as a translation of the English term "records management"). Despite the similarity of these concepts, according to some researchers, there is still a difference in domestic practice. The concept of "document

management" focuses on complexes of documents (these are different documentation systems, as well as types and varieties of documents), while the concept of "document management" may focus on documents as separate objects.

The massive development of automated information systems has become a factor for national documentary studies that has stimulated new areas of documentary research and new practical solutions. In the 1980s, document studies began to more actively merge with documentary studies as an applied part of cybernetics, which studies the management of large dynamic document systems, i.e. systems where information circulates in the form of documents.

It should be emphasised that the active introduction of computers in the processing of management documentation has led to fundamental changes in the documentary environment, which, with some reservation, can be called revolutionary, as fundamentally new media and methods of recording, reading, searching, and storing documented information have emerged. All of these innovations required extensive research. One of its first results was the emergence of the term "documentary management support" (DMS), a new term in documentary studies [23].

In the 1980s, a number of factors emerged that changed the established views on the use of computers in management. Among these factors, the development of microelectronics, the emergence of microcomputers available to ordinary users, and the creation of various types of computer networks took a prominent place.

Scientific and technical developments have made it possible to really approach the design of an automated system that could be used in the practice of rational organisation of documentation and all subsequent document processing processes in order to avoid excessive duplication and unnecessary documentation, to ensure information retrieval and reduce the storage of document arrays. Such a system is called a "documentary support system" (DSS) [23].

The urgent task of document science at that time was to develop the concept of a document management system, i.e. to determine its fundamental content, directions of automation of work with documents in order to increase the efficiency of management activities and reduce the volume of documentation.

In the 1990s, the situation in the field of automation of documentary support for management was changing, and the prerequisites for eliminating shortcomings in the field of document management were gradually being created. Changes are taking place in the field of new information technologies. Compared to the previous decade, the market for information technology and software is now offering an opportunity to purchase any modern information systems and technologies. There is a growing demand for modern management documentation systems in public administration and, especially, in commercial organisations. Consequently, more attention is being paid to document management issues.

Scientists have come up with a hypothesis that at the present stage, the technical equipment of management structures is often ahead of the methodological support for the use of new technologies, which leads to inefficient and unsystematic use of them [23]. Nowadays, there is a tendency towards active development of modern models of information systems, and innovative technologies are being rapidly introduced into the automated document management system.

The study of the experience of designing automated control systems reveals a new trend: if initially information needs were met through the introduction of local networks, then later the same goals are achieved by creating open local networks consisting of personal computers interconnected by means of communication. Equipping these networks with the necessary interfaces and software environments leads to the creation of powerful information service systems (the so-called client–server systems) [23].

A new way of implementing client–server technology is intranet technology. This technology summarises the experience gained on the Internet in the so-called distributed environment. When using intranet technology, an organisation integrates the software products and hardware it uses into a common information environment with uniform rules for creating and consuming information.

To understand modern ACS, it is important to consider such concepts as "workflow" and "groupware".

Workflow is the full or partial automation of a business process, in which documents, information or tasks are transferred from one process participant to another to perform actions. This system is a convenient interactive tool for managing business processes in real time. The relevant documentation is strictly linked to management procedures based on a clear division of work, functions, and tasks among employees of the management apparatus. The document flow seems to be superimposed on management processes.

Groupware is software that allows you to organise the joint work of employees of an organisation, i.e. their cooperation in the process of performing management tasks. Document management systems focus on creating databases of documented information.

In today's environment, when organisations face shortcomings in their document management, it is necessary to strengthen the transition to more efficient document management, taking into account the emergence of new information technologies.

ACSs are divided into three broad groups:

1. Higher-level (corporate) systems. They are characterised by the greatest functionality, covering all standard documenting and processing processes in organisations. Systems of this level include all typical computer technologies and are capable of managing documents on various client and server platforms. These systems can be used in complex hierarchical structures (ministries, banks, corporations, city administrations, etc.).
2. Mid-level systems. These systems are designed to implement several/some high-level functions in the field of document text management, primarily related to searching and extracting data from information arrays.
3. Lower-level systems. They provide only basic functions of searching and retrieving documents. These systems are usually of "boxed" design, designed to implement some similar search operations (for example, in text editor mode) [23, p. 196].

The need for efficient management of electronic documents led to the creation of electronic systems in the 1980s.

An electronic document management system (EDMS) is an organisational and technical system that ensures the creation, access control and distribution of electronic documents in computer networks, as well as control over document flows in an organisation. Such software is designed to organise and store various types of documents. This type of system is more commonly referred to as a document management system, a more general type of data storage system that helps users organise and store paper or digital documents.

Electronic document management provides a way to centrally store large volumes of digital documents [24]. Many of these systems include features for efficient document retrieval.

Properties of the document management system:

ensuring such properties of documents as authenticity, reliability, integrity, and suitability for use;
Ensuring the reliability of document management, i.e. the ability to create, use and store documents in a long-term and correct manner in accordance with established procedures;
ensuring the integrity and unity of the entire set of actions and procedures for document management;
ensuring that all document management activities comply with established requirements (external and internal);

Ensuring the comprehensiveness (complexity) of document management by covering all types of activities, all formats of data presentation in documents, and all types of information carriers.

The document management system should implement the following functions:

entering documents into the document management system;
registration;
classification;
access and protection;
storage and security of documents;
use of documents, control of their movement and use;
examination of the value of documents;
selection (transfer) of documents for storage or destruction.

Information Management Systems (IMS) or portals provide information aggregation, information management and information transfer via the Internet/intranet/extranet. The portals also provide access to applications via a standard Web navigator.

Content Management Systems (CMS) provide content creation at the object level for their subsequent reuse. In such systems, information is available not in the form of documents but in the form of smaller objects, which makes it easier to exchange information between applications. For example, managing Web content requires the ability to manage objects of different content that can be included in a Web presentation.

Basic principles of electronic document management:

- one-time registration of a document;
- the ability to perform various operations in parallel to reduce the time required to move documents and increase the efficiency of their execution;
- continuity of document flow;
- a single database of documentary information for centralised document storage and the elimination of duplicate documents;
- an efficiently organised document search system;
- a sophisticated reporting system that allows you to control the movement of documents in the document flow process.

In accordance with the basic principles of electronic document management, EDMS provides the following functions:

– centralised document management—EDMS allows you to quickly change the forms of documents used in the organisation;
– Document lifecycle support—EDMS allows for strict control of the document lifecycle, taking into account the requirements of the corporate environment, as well as industry standards and legislation;
– Teamwork on documents—EDMS allows you to organise teamwork on a document; specialists located in different offices can participate in it;
– Ensuring confidentiality—EDMS provides the ability to sign documents using an electronic signature and encrypt them;
– Document routing—EDMS provide automatic transmission of a document to the right person. Integration with other systems—EDMS should and can be integrated with other enterprise management systems, such as accounting, production, financial, analytical, etc.
– access control—EDMS allows you to differentiate between the powers of employees and control access to documents.

The issue of classifying EDMS is quite complex due to the rapid development of the market for these systems. Today, there are the following main types of EDMS:

1. DMS designed to organise document storage. Systems of this type are used for specific vertical and horizontal applications (sometimes they have industry-specific applications). They provide the full life cycle of document management, as well as storage and retrieval of documents in their original formats for grouping them into folders. The most well-known developers of EDMS systems are Documentum (Documentum system), FileNet (Panagon and Watermark systems), Hummingbird (DOC Open system), etc.
2. Corporate DMS. Systems of this type provide a corporate infrastructure (available to all corporate users) for creating documents, collaborating on them and publishing them. DMS are implemented as mass or general corporate technologies. Lotus (Domino.Doc system), Novell (Novell GroupWise), Open Text (LiveLink system), Keyfile, Oracle (Context system), iManage, etc. are engaged in the development and promotion of corporate DMS.
3. Content Management Systems. This type of system provides content creation, access and management, and content transfer (down to the level of document

sections and objects for further reuse). The availability of information in the form of smaller objects rather than documents makes it easier to exchange information between applications. The world's most popular content management systems include Adobe, Excalibur, BroadVision, Documentum, Stellent, Microsoft, Divine, Vignette, and others.

4. Workflow Management Systems. Systems of this type are designed to provide a route for workflows of any type (determining the route of files) within corporate structured and unstructured business processes. They are used to increase the efficiency and controllability of corporate business processes. The developers are Lotus (Domino/Notes and Domino Workflow systems), Jetform, FileNet, Action Technologies, Staffware, etc.

All of the above types of systems are among the simplest implementations of EDMS, the so-called electronic document management systems. However, businesses and organisations whose activities involve the constant processing of a large number of different documents use higher-level EDMSs, which are commonly referred to as Product Data Management (PDM) systems. Such systems fully or partially perform the functions of electronic document management systems. An essential component is the ability to manage the flow of work and the route of documents.

The most powerful EDMSs are the so-called ERP (Enterprise Resource Planning) systems. These systems, in addition to the concepts of "document" and "product", operate with the concept of "resource". The main functionality of such systems is to plan, analyse and organise the consumption of resources, while the tools for managing documents and product data play a supporting role. Usually, there are special electronic document management modules that are built into ERP systems. However, the capabilities of these modules are quite limited, as it is almost impossible to create a universal and fully functional ERP system.

For large enterprises, SAP R/3, Oracle Applications, and Baan can be used as ERP systems. The less powerful but cheaper Navision system from Microsoft is also popular.

GroupWise WorkFlow Professional (Novell) is a graphical version of GroupWise WorkFlow that integrates seamlessly with email to organise teamwork and improve workflows, and contains a wide range of icons (graphic elements) to describe workflows.

The Saros Document Manager system (Saros Corporation) provides two-level document management—a library server and a client site, universal access to data warehouses, attribute search, automation of routine work (printing, archiving, e-mail exchange), a unified security system and information lifecycle management.

The Action WorkFlow system (Action Technologies) is designed to automate information flows in Lotus Notes or Microsoft SQL Server, supports standard document flow management technologies, graphical modelling of business processes, model integrity checking and optimisation, calculation of process execution time and cost, and generates reports.

The EDMSuite system (IBM) includes the FlowMark document management system, graphic document processing tools, provides three-level distribution of access rights, and document version control.

The FormFlow system (Symantec) is designed to fully meet all the needs of an organisation for automating business, production processes, business processes based on electronic forms.

Documentum (http://www.documentum.com/) is a global market leader in ECM (Enterprise Content Management) systems. It is a full-featured platform designed to manage unstructured enterprise information (various types of documents, digital media data, website content). The Documentum platform allows not only to manage enterprise documents at all life cycle stages, but also to solve the problems of complex automation of various business processes, providing process-oriented communication between different information systems. The document management system contains tools that allow you to create applications in the Documentum environment. Therefore, Documentum can be viewed as a platform designed to create distributed archives, maintain quality standards, manage projects in distributed groups, organise corporate records management [25], dynamically manage the content of corporate portals, manage digital media data, and interact with scanning/recognition tools.

The use of modern open source technologies enables the use of external development tools to create Documentum applications.

The LanDocs system is a two-level software package designed to automate the functions of registering and filling in document records, sending documents, tasks, orders, and provides control over the status of documents, versions, creating reports, and archiving. The workflow component is implemented in a client/server architecture based on industrial DBMSs: Oracle or Microsoft SQL Server. The software for centralised management of document storage in the electronic archive is implemented as a separate server. The LanDocs mail service is designed in such a way that employees who have a special LanDocs client component installed can receive and report on task messages using a standard Microsoft Exchange or Lotus Notes mailbox.

Docs Fusion and Docs Open. These products are developed by Hummingbird (http://www.hummingbird.com/). They are among the most popular electronic archive systems in the world. The systems can be effectively used both in organisations with a large number of employees (thousands of people) and in small firms (5–6 people). They are designed for organisations that are involved in intensive document creation and editing, such as head offices, consulting companies, government agencies, etc. To store system data, you need to use Microsoft SQL Server or Oracle. The file system is used as a storage for the documents themselves. The systems are open source and include development tools for creating specialised applications or integrating with other systems.

Optima Workflow is a comprehensive system for managing workflows and organising confidential document management. It is designed to formalise standard document workflow procedures in organisations where such work is a daily practice. The system automates document registration processes according to the rules of office workflow, implements mechanisms for annotating and collecting resolutions,

and delivering reports on the execution of orders. Optima Workflow uses Microsoft Exchange as a document server, so it is advisable to use it in those companies where Microsoft Exchange is already used for its intended purpose—as a mail server.

Advantages of Using EDMS

The use of EDMS provides tactical and strategic benefits.

Tactical benefits are determined by the reduction in costs of implementing the EDMS associated with the release of physical space for storing documents; reduction in the cost of copying and transferring paper documents; reduction in personnel and equipment costs, etc.

Strategic benefits include those associated with improving the efficiency of an enterprise or organisation. Such benefits include:

- the possibility of collective work on documents (which is impossible with paper-based workflow);
- accelerating the search and selection of documents (by various attributes);
- improving information security by making it impossible to work in the EDMS from an unregistered workstation, and assigning each EDMS user its own information access authority;
- Increase the safety of documents and the convenience of their storage, as they are stored electronically on the server;
- improving control over the execution of documents.

Almost all systems provide a good level of repository and library services for managing electronic content (e.g. images and office documents), each with an advantage in its own area. For example, Open Text and iManage's systems are the best at managing office documents. However, systems from Tower Technology, FileNet, IBM, and Identitech are particularly strong in managing images of larger products.

Development trends

Many systems are expanding the functionality of record management, for example, adding classification functions.

Methods of physical deletion of records and indexes at the end of their life cycle are gradually being implemented.

Another notable trend has been the interpenetration of open-type electronic document management systems and workflow management systems. This means adding workflow management modules and document routes directly to the electronic document management system. Documentum, DOCS Open/Fusion from Hummingbird, and others have taken this approach. Many manufacturers of electronic document management systems have decided to add to their products the ability to combine with higher-level EDMSs, such as PDM and ERP.

One important trend among the EDMS class of electronic document management systems is the combination of functionality from different subclasses of these systems.

3. Passing, processing and sending electronic documents

To ensure the work with electronic documents and their timely execution, the institution determines (develops) and approves schemes for the passage of electronic documents between the enterprise's units for all types of documents. These schemes provide employees with access to electronic documents. The development of schemes for the flow of electronic documents is carried out taking into account the regulations on the enterprise or institution and their structural units, in accordance with administrative documents on the distribution of responsibilities between the head of the enterprise and his deputies, job descriptions, classifiers of issues of the enterprise's activities [26], and the nomenclature of cases.

After preliminary review of the electronic document and its registration, depending on the electronic document flow patterns, the records management service notifies management or employees of the receipt of electronic documents and links to their files in the enterprise's or institution's information system.

Based on the results of the review of the electronic document, the management creates an electronic resolution that is automatically attached to the registration and control card of the electronic document.

To automatically add a resolution to the registration and control card of an electronic document, the information automated system must provide an appropriate interface that allows management to enter the text of the resolution, select a list of executors and apply an electronic digital signature [27] to the resolution.

Upon creation of a resolution, the information-automated system must ensure automatic generation and sending of notifications to the executors specified in the resolution, as well as to the clerical service. Such a notification must contain the content of the resolution, the name of the electronic document file to which the resolution was created, and a link to this file in the information automated system. The notification to the executor shall be the basis for automatic granting of access to the electronic document, if it does not contradict the security policy of the enterprise, institution and requirements of the legislation on technical protection of information. If access is granted automatically, information about this is automatically sent to the institution's information support service.

The chief executor responsible for the execution of an electronic document shall determine the deadlines for submitting proposals, the procedure for approving and preparing a draft electronic document, guided by the relevant schemes for the processing of electronic documents approved by the institution. If an electronic document needs to be corrected, the chief executor shall coordinate this with the office management service of the enterprise or institution.

Together with the draft electronic document, a new registration and control card for the new electronic document is created in the institution's information and automation system, the draft electronic document file is named in accordance with the requirements for naming electronic document files depending on the purpose of the document (internal, outgoing), and the new registration and control card contains a link to the draft electronic document file in the institution's information and automation system. After creating the final version of the draft electronic document, the chief executor notifies the records management service and sends it for signature

according to the workflow defined in the institution for the relevant type of electronic document. Access to the draft electronic document is granted according to the established sequence. To do this, a message is sent containing a link to the draft electronic document file and the files of all documents on the basis of which this draft was drawn up.

The first electronic digital signature is applied to the document in accordance with regulatory requirements.

An electronic document received at the appropriate address shall be rejected if the addressee does not have reliable means of electronic digital signature, if it is received at the wrong address, if it is infected with a virus, or if the integrity and validity of all electronic digital signatures affixed thereto is negatively verified.

Preliminary review of an electronic document is carried out in visual form. Determination of whether an electronic document requires mandatory review by the manager or other officials in accordance with their functional responsibilities, the need to register it, and setting deadlines for the execution of this document by structural units or direct executors is carried out in the same manner as for paper documents.

Incoming, internal and outgoing electronic documents are registered in one system along with the corresponding paper documents.

Registration of incoming electronic documents is carried out in the same manner as for incoming paper documents. Control over the execution and prompt use of information contained in electronic documents shall be exercised in the same manner as for paper documents.

To ensure the registration, accounting, search and control of the execution of an incoming electronic document, a registration and control card is filled out in electronic form.

After registering an incoming electronic document, the addressee sends a notification to the sender within two days of its acceptance and registration.

Electronic documents are processed in the same manner as paper documents.

An electronic document shall be signed or approved by affixing electronic digital signatures of the relevant officials. At the time of affixing the last electronic digital signature, the date and its registration number shall be technologically and/or organisationally ensured by affixing the date and registration number to the created electronic document.

If an electronic document is not signed or approved by a manager or other official, the registration of this document shall be cancelled, and the executor shall be informed of the rejection of the document.

An electronic seal shall be affixed to an electronic document in accordance with the law. This procedure shall be performed only after the electronic document is signed or approved.

Electronic documents shall be addressed in accordance with the same requirements as for hard copy documents. Prior to sending an outgoing electronic document, its integrity and the validity of all electronic digital signatures attached thereto shall be verified in accordance with the same requirements as for incoming documents.

Sending and transmission of electronic documents by the author or intermediary is carried out in electronic form by means of information, telecommunication, information and telecommunication systems or by sending electronic media on which the document is recorded [20]. Unless the author and the addressee have previously agreed otherwise in writing, the date and time of sending an electronic document is the date and time when the sending of the electronic document cannot be cancelled by the person who sent it.

In case of sending an electronic document by sending it on an electronic medium on which the document is recorded, the date and time of sending shall be the date and time of its delivery for transmission [20].

The requirements for confirming the receipt of a document established by law in cases of sending documents by registered mail or handing them over against receipt do not apply to electronic documents. In such cases, the confirmation of receipt of electronic documents is carried out in accordance with the requirements of the Law [20].

If the addressee does not receive a notification of acceptance and registration or rejection of an electronic document within two business days, the sender shall take additional measures using other means of communication to receive a notification from the addressee.

If the sender receives a notification from the addressee that an electronic document has been rejected, the sender shall take measures to eliminate the reasons for the rejection and ensure that the document is sent again. If such a notification is received from an addressee who does not have a reliable digital electronic signature, the addressee shall be sent the relevant document on paper.

An electronic document shall be approved by affixing an officer's electronic digital signature to it.

4. Organisation of control over the execution of electronic documents

To ensure the timely and proper execution of documents (collection and processing of the necessary information, preparation of a draft document: response, its execution, approval and submission for signature (approval) to the management of the company (structural unit), and, if necessary, preparation for sending to the addressee, etc.), it is necessary to control this process. Control over the execution of documents involves ensuring their timely and high-quality execution. All registered documents are subject to this control. It is entrusted to the control service, which is created in accordance with the institution's office work instructions.

Control has its own specifics that distinguish it from other management functions. This makes it possible to specialise in control activities for certain departments or specific employees. That is why direct control over the implementation of documents is entrusted to specially created control services, departments, sectors or responsible persons.

Direct responsibility for the execution of a particular document lies with the persons specified in the administrative document (order, decision, instruction, etc.), the resolution of the head and direct executors.

Control over the execution of documents covers the following stages:

– taking documents for control;
– determining the forms and methods of control;
– checking the timely transfer of documents to the contractors;
– monitoring the status of execution;
– withdrawal of documents from control;
– control over the filing of the executed document in the case file;
– recording, summarising and analysing the results of document execution;
– informing the company's management about the progress and results of the documents' implementation [28].

Control cannot exist in isolation and be exercised only for the sake of control. It is carried out in accordance with the peculiarities and specific content of their management activities and is aimed at a specific result and ways to achieve it, eliminate and take into account obstacles in the exercise of powers.

Control activities have a number of requirements that must be met:

(1) subordinate, i.e. control should be exercised only within the framework of specific regulatory requirements;
(2) systematic, i.e. regular in nature;
(3) timely, i.e. conducted in a timely manner, which significantly increases its effectiveness;
(4) comprehensive, i.e. cover the most important issues, apply to all services and structures of the controlled bodies;
(5) in-depth, i.e., not only those units with poor performance, but also those with good performance should be subject to audit;
(6) objective, i.e. free from bias;
(7) public, i.e. its results should be known to those who were subject to control;
(8) effective (efficient) [29].

Control is exercised over the implementation of all registered documents containing tasks and whose implementation is subject to mandatory control.

List of documents subject to mandatory control.

The efficiency of control over the execution of documents is ensured by the List of Documents Subject to Mandatory Control over Execution (hereinafter—the List). The List is drawn up taking into account the specifics of the organisation's activities and structure.

In practice, two types of Lists are used:

– The first contains only a list of types of documents subject to mandatory control over execution;
– the second contains a list of documents with the maximum deadlines for each of them.

List of documents subject to mandatory control over implementation:

- Resolutions and decisions of state and local authorities (councils);
- orders from higher-level organisations;
- orders of the head of the organisation;

- Decisions of the organisation's collegial bodies (management board, council, directorate, etc.) containing specific instructions;
- instructions from management, including those given during operational meetings;
- appeals from people's deputies of Ukraine;
- orders of state control and supervision authorities;
- resolutions and conclusions of the Accounting Chamber Board;
- submitting a request to the prosecutor to eliminate violations of the law, the causes and conditions that led to them, to bring persons to statutory liability, to compensate for damage, to cancel a regulatory act or its individual parts or to bring it into compliance with the law, to stop illegal actions or omissions of officials and employees;
- the prosecutor's decision to initiate administrative proceedings against a person;
- requests for public information from individuals and legal entities, associations of citizens without legal entity status;
- Citizens' appeals (proposals, applications, petitions, complaints);
- letters of instruction and letters of request from higher-level organisations;
- telegrams raising issues that require urgent resolution.

The list of documents subject to mandatory control in a particular institution may be expanded.

The second type of the List is more convenient and efficient.

To speed up the implementation of the document control system, it is advisable to approve the List separately—by order of the head or by putting an approval stamp. And after the approval of the workflow instructions, the List will become an appendix to it.

The list of documents subject to implementation control is regularly reviewed to introduce new or eliminate outdated provisions, clarify and improve wording.

Each document has its own deadline set out in a regulatory act, administrative document or resolution of the company's management.

The deadlines for the execution of documents are calculated in calendar days, from the date of signing or approval for documents created by the institution or from the date of receipt for incoming documents.

Deadlines may be standard and individual. For certain, most widespread categories of documents, standard deadlines are established in accordance with acts of the highest legislative and executive authorities of Ukraine. In other cases, the timeframe for processing documents should not exceed 10 days. Longer terms are set for documents that are complex in nature.

Individual deadlines are set for the most important documents by the head of the institution. The final date of execution is recorded in the text of the document.

If the task requires urgent completion, the document must specify a specific deadline for completion.

If an incoming document contains a deadline by which a response is expected, it must be met. The deadline can be changed only by the manager's instruction in the

following order: standard deadlines—by adopting a new act, individual deadlines—by the manager who set them.

The individual time limit for execution of a document may be changed only upon the instruction of the officer who set it, or, in his/her absence, of the person replacing him/her. If necessary, the time limit for execution of a document may be extended at the reasonable request of the executor, which shall be submitted no later than three business days before the expiry of the established time limit, and in respect of a document that does not specify a time limit, until the expiry of a 30-day period from the date of its registration.

If the deadline is changed, the new deadline, date and signature shall be affixed. The relevant changes shall be made to the registration and control card or registration data bank.

Persons responsible for monitoring the execution of documents

One of the deputy heads of the institution shall organise control over the performance of tasks specified in acts of state bodies and instructions of senior officials in accordance with the distribution of functional responsibilities between the management.

Direct control over the execution of documents is vested in the control service (a special unit) or an official responsible for control. In small enterprises, this function is most often performed by the secretary of the head of the institution.

In structural divisions, the person responsible for office work is responsible for direct control over the execution of documents.

Methods of control

Control over the execution of documents is carried out using a registration and control card or an automated information system (database).

The registration and control cards of documents under control are grouped in a file by the terms of execution of documents, executors, groups of documents (orders of the head of the institution, instructions of higher state bodies, decisions of the collegial body of the institution, etc.). Other copies of registration and control cards are used to form control files in structural units.

Several registration and control cards can be created for one controlled document. Their number depends on the number of executors or the deadlines for completing individual tasks specified in the document.

If several executors are identified but only one of them is responsible, the registration and control card is drawn up for him only.

Information on the progress of the document, obtained by telephone or during an inspection of the work of the executing structural unit, shall be entered in the "Control marks" column of the registration and control card.

Automated control over the execution of documents is carried out using special computer programs or is a component of an office automation system or an electronic document management system. It involves the automatic generation of information on their execution.

Checking the progress of documents and their knowledge of control

The progress of documents is checked at all stages of the document's passage before the expiry of its execution period (preventive control by means of reminders) in the following order:

- tasks for the next year—at least once a year;
- tasks for the following months of the current year—at least once a month;
- tasks for the current month—every ten days and five days before the deadline or upon request.

If the company has an electronic document management system in place, the executor is sent an electronic notification of the scheduled date of execution of the document.

The forms and methods of control in the context of work automation are determined in accordance with the scheme of electronic document flow.

For effective control over the execution of electronic documents, the executor shall notify the control service of all stages of document execution. The control service shall make all relevant marks in the electronic document's RCC.

To ensure effective analysis of the results of electronic document execution, an institution's automated information system should ensure that electronic documents are grouped by their execution time, executors, etc.

The institution's automated information system shall automatically add to the registration and control card of the electronic document information on the time of reading the contractor's message, execution of the electronic document, receipt of proposals (comments), changes to the draft electronic document, and the time of the contractor's familiarisation with the electronic document or with proposals (comments) or the draft electronic document.

The control service ensures that the registration and control card of the electronic document contains notes on the new deadlines for the execution of the document and the basis for their extension with the electronic digital signature of the head of the institution or other official who gave the execution order, if the deadlines were extended at the reasonable request of the executor.

After execution, the document is removed from control, in particular after completion of tasks, requests, notification of results to interested legal entities and individuals, or other confirmation of execution.

A document may be removed from control only by the head of the institution or his or her deputies who set the control period in their resolution on the document, or on their behalf by the institution's control service.

Documents with standard deadlines are removed from control by a decision of the control service.

Information about the execution of the document and its removal from control is entered into the registration and control card.

2 Conclusions

Thus, the document flow at an enterprise is a system that materialises the processes of collecting, transforming, storing information, as well as management processes: preparation and decision-making, and control over their implementation.

References

1. Palekha, Y.I.: Organisation of modern office work: a textbook. Kyiv: Condor 194 c (2007)
2. Gerashchenko, M.M.: Information technologies in office management and personnel work: a textbook. Novosibirsk: SibAGS Publishing House, 184c (2011)
3. Khrashchevskyi, R., Klobukov, V., Kozlovskyi, V., Akhramovych, V., Lazarenko, S.: Method of calculating information protection from mutual influence of users in social networks. Int. J. Comput. Netw. Inf. Secur. (IJCNIS) **15**(5), 27–40 (2023). https://doi.org/10.5815/ijcnis.2023.05.03
4. Kukarin, O.B.: Electronic document management and information protection: a textbook / edited by Prof. N.V. Hrytsiak. Kyiv, 2015. 84 c. http://academy.gov.ua/infpol/pages/dop/2/files/dcc74a43-a939-4314-8f50-f6b1e80cf498.pdf. Accessed 20 Macrh 2022
5. Larin, M., Ryskov, O.: Document management on the basis of the international standard ISO 15489–2001: methodological manual. Moscow, 110 p. (2005)
6. Baronov, V.V.: Information technologies and enterprise management. Baronov, V.V., Kalyanov, G.N., Popov, Y.N. et al. Moscow: Aichi Company, 328 c (2004)
7. Naranong, S., Auwatanamongkol, S.: A block permutational steganographic algorithm for scanned documents and other images. Int. J. Modern Educ. Comput. Sci. (IJMECS) **13**(5), 42–57 (2021). https://doi.org/10.5815/ijmecs.2021.05.05
8. Tanira, A.H., Ashour, W.M.: A Hybrid unsupervised density-based approach with mutual information for text outlier detection. Int. J. Intelli. Syst. Appl. (IJISA) **15**(5), 41–56 (2023). https://doi.org/10.5815/ijisa.2023.05.04
9. Alade, S.: Design and implementation of a web-based document management system. Int. J. Inf. Technol. Comput. Sci. (IJITCS) **15**(2), 35–53 (2023). https://doi.org/10.5815/ijitcs.2023.02.04
10. Tashev, A., Takenova, Z., Arshidinova, M.: Algorithms for solving problems of resources allocation in the management of business processes in educational organizations. Int. J. Modern Educ. Comput. Sci. (IJMECS) **15**(5), 14–27 (2023). https://doi.org/10.5815/ijmecs.2023.05.02
11. Rajan, R., Jose, D., Gurumoorthy, R.: Tangent search long short term memory with aadaptive reinforcement transient learning based extractive and abstractive document summarization. Int. J. Modern Educ. Comput. Sci. (IJMECS) **15**(6), 56–72 (2023). https://doi.org/10.5815/ijmecs.2023.06.05
12. Fedushko, S., Syerov, Y., Kolos, S.: Hashtag as a way of archiving and distributing information on the internet. CEUR Workshop Proceedings. 2019. Vol. 2386: Workshop Proceedings of the 8th International Conference on "Mathematics. Information Technologies. Education, pp. 274–286 (2019). http://ceur-ws.org/Vol-2386/paper20.pdf
13. Specialised systems of automation of office work and document flow. Studies in archival affairs and documentary studies. T. 8. C. 142–146.
14. Adebayo, O., Adebayo, B., Abdullah, M., Enemona, O., Abdulazeez, L.: Development of an electronic secure students' industrial works experience scheme placement system. Int. J. Inf. Technol. Comput. Sci. (IJITCS) **14**(2), 31–44 (2022). https://doi.org/10.5815/ijitcs.2022.02.03
15. Electronic document management in Ukraine: how it works. https://ain.ua/2019/03/12/kak-rabotaet-elektronnyj-dokumentooborot-v-ukraine/. Accessed 20 March 2022

16. Features of the use of electronic digital signature. https://ktpu.kpi.ua/wp-content/uploads/2016/02/osoblivosti-zastosuvannya-elektronnogo-tsifrovogo-pidpisu.pdf. Accessed 20 March 2022
17. Vatamaniuk-Zelinska, U.Z., Sushko, V.S.: Prospects for the use of electronic digital signature in state structures. https://financial.lnu.edu.ua/wp-content/uploads/2015/11/12-1.pdf. Accessed 20 March 2022
18. Sychev D.A. Modern systems of electronic documentation management and trends in their development. https://mai.ru/upload/iblock/045/sovremennye-sistemy-upravleniya-elektronnoy-dokumentatsiey-i-tendentsii-ikh-razvitiya.pdf. Accessed 20 March 2022
19. On Approval of the Procedure for Working with Electronic Documents in Record Keeping and Preparing Them for Archival Storage: Order of 11.11.2014 No. 1886/5. https://zakon.rada.gov.ua/laws/show/z1421-14#n24. Accessed 20 March 2022
20. On electronic documents and electronic document management: Law of Ukraine of 01.01.2022. NO. 851-IV. https://zakon.rada.gov.ua/laws/show/851-15#Text. Accessed 20 March 2022
21. On electronic digital signature: Law of Ukraine of 22.05.2003. NO. 852-IV. Expired on 07.11.2018. https://zakon.rada.gov.ua/laws/show/852-15#/852-15#Text. Accessed 20 March 2022
22. Komova, M.V., Peleshchyshyn, A.M., Bilushchak, T.: Management of documentary processes: a textbook. Lviv: Lviv Polytechnic Publishing House, 188 p. (Series "Information.Communication. Documentation"; issue 2) (2013)
23. Larin, M.V.: Documentation management in organisations. Moscow: Nauchnaya kniga, 288 c (2002)
24. Tiurmenko, I., Bozhuk, L., Struk, I., Syerov, Y.: Digital documentary collections of national cultural heritage on the Ukrainian regional state archives websites. Developments in Information & Knowledge Management for Business Applications. Studies in Systems, Decision and Control, vol. 421. Springer, Cham (2022). https://doi.org/10.1007/978-3-030-97008-6_20
25. Eben Exceline, C., Nagarajan, S.: The security of blockchain-based electronic health record: a systematic review. Int. J. Comput. Netw. Inf. Secur. (IJCNIS) **15**(6), 103–117 (2023). https://doi.org/10.5815/ijcnis.2023.06.09
26. Khaletska, L., Klynina, T., Fedushko, S., Yurchenko, O.: Impact of social networks in the information activity of the Ukrainian institute of national remembrance: from theoretical understanding to practical implementation. Developments in Information & Knowledge Management for Business Applications. Studies in Systems, Decision and Control, vol. 421. Springer, Cham. Pp. 403–423 (2022). https://doi.org/10.1007/978-3-030-97008-6_18
27. Application of electronic digital signature for information protection. https://ua.ikmj.com/digital-signature/. Accessed 20 March 2022
28. Zagoretska, O.: General office work at enterprises of various forms of ownership. Part.6. Organisation of execution of official documents. https://undiasd.archives.gov.ua//doc//zmi/SR_08_2013(1).pdf. Accessed 20 March 2022
29. Organisation 16of control in the system of public authorities: Information and methodological material / M.I. Bayuk, M.I. Voit, G.V. Matkovsky. Khmelnytskyi. 135 c (2013)

In-Depth Examination of the Effective Use of Social Networks for Communication in United Territorial Communities: Navigating the Digital Landscape

Vitalina Horova, Zoriana Sverdlyk, Yuriy Syerov, and Liliya Lesyk

Abstract The article explores the application of social media (as an accessible tool and an important component of a small territory's information space, an effective platform for the consolidation of citizens according to the similarities of their needs and interests) in the public communication of the territorial community. It attempts to structure its types and functional load. The information and communication potential is analyzed, as compared to the society's site and the role of society in general. It focuses its attention on Facebook, being the most popular of social networks, and highlights its advantages and disadvantages. Based on the study of official Facebook pages/groups of urban united territorial communities in the Vinnytsia region, the level of communication activity of subscribers/participants was traced. After analyzing the level of audience involvement (number of subscribers relative to the population), posting activity (number of posts per day/month), user activity (set of reactions to the publication), and feedback (quick access button), we obtained data indicating a high rate of the presence of posts on the page/in the local community group, which testifies to the regularity of their publications. At the same time, the assessment shows that communities do not take full advantage of Facebook. First of all, the level of audience involvement and user activity (response to posts) needs to be increased. This can be achieved by expanding the topic and improving the quality of information content, as well as working to increase the Post Organic Reach.

V. Horova
Institute of Art, Folkloristic and Ethnology Studies of National Academy of Sciences of Ukraine Named After M. Rylsky, M. Hrushevsky Street, 4, Kyiv 01001, Ukraine

Z. Sverdlyk
Kyiv National University of Culture and Arts, E. Konovalets Street, 36, Kyiv 01601, Ukraine

Y. Syerov (✉) · L. Lesyk
Lviv Polytechnic National University, Lviv 79007, Ukraine
e-mail: yurii.o.sierov@lpnu.ua

Y. Syerov
Faculty of Management, Comenius University Bratislava, Odbojárov 10, Bratislava, Slovak Republic

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2024

P. Štarchoň et al. (eds.), *Data-Centric Business and Applications*, Lecture Notes on Data Engineering and Communications Technologies 213,
https://doi.org/10.1007/978-3-031-62213-7_11

Keywords Information · Communication · Social networks · Facebook · Communication activity · Information and communication space · United territorial community

1 Introduction

The rapid advancement of technology and the widespread adoption of social media platforms have revolutionized the way people communicate and interact with one another. In recent years, there has been an increasing interest in the management of information and communication in social networks, as organizations and individuals seek to leverage these platforms for various purposes, including marketing, customer engagement, and social activism. As a result, the field of information and communication management in social networks has emerged, encompassing a range of theoretical and practical approaches to understanding and optimizing communication processes in social media environments.

This scientific article aims to contribute to the growing body of knowledge in this field by exploring the key concepts, theories, and methodologies that underpin effective information and communication management in social networks. Drawing on relevant literature and case studies, the article will examine the role of social media in facilitating communication and information exchange, as well as the challenges and opportunities associated with managing information in these dynamic and often complex environments. The article will also discuss emerging trends and best practices in social media management, with a particular focus on the importance of strategic planning, engagement, and analytics for achieving effective communication outcomes. This article seeks to provide a comprehensive overview of the field of information and communication management in social networks, highlighting its relevance and significance for organizations and individuals in today's interconnected and rapidly changing digital landscape.

In the context of the global development of modern society, there is a need to create and form an information space (a structure that unites the results of communication activities) of the territorial community. Information and communication technologies have confidently taken a priority place in the construction of such a communication system. The presence of the community in the Internet space will contribute to the establishment of mechanisms for public participation in local government, development, and promotion of cultural traditions in a small area. In addition, the skillful application of innovative approaches is important in revealing the ethnocultural and tourist potential of the community, as well as in inventing tools to build an effective system of self-organization of the population.

Recently, the idea of changing the administrative-territorial structure of our state has been increasingly implemented. Under a constitutional amendment to the Law of Ukraine "On Local Self-Government in Ukraine" [1] in July 2020, a clear definition is given to the concept, structure, and functions of the territorial community as a set of residents united by permanent residence within the village, town, city, which are

independent administrative-territorial units, or voluntary associations of the residents of several villages, settlements or cities, which have a single administrative center. At the same time, the Verkhovna Rada of Ukraine adopted Resolution No. 3650 [2], according to the provisions of which 136 new districts within the existing oblasts were formed in Ukraine instead of the 490 old ones. The main reason for the change in the existing zoning was the uneven distribution of tasks with the same responsibilities of district authorities, caused by different population densities.

Just before it, in June 2020, the Cabinet of Ministers of Ukraine adopted the relevant regulations on the definition of administrative centers and approval of the territories of the communities of the oblasts. As a result, 1469 territorial communities were created (including 31 in the uncontrolled territory within the Donetsk and Luhansk oblasts) [3].

The purpose of these innovations is to improve the system for allocating public funds, to standardize the liability of the district authorities towards the governmental authority and vice versa, to improve and decentralize the country's territorial division.

However, immediately after the formation, the communities faced a number of key tasks, namely: to promptly inform the population about the innovations, to highlight plans for further work, structure, responsibilities, and responsibilities of the newly formed units.

Community leaders, in order to solve the set tasks, began to actively involve the system of social networks. The fact is that today, in the conditions of anti-quarantine measures and restriction of contacts, the Internet space has become the platform where every day there are more and more various discussions of strategies, suggestions and comments. At the same time, social networks come to the fore in this process as the main way of community communication. Accordingly, the problem of structuring their types, functions, and capabilities, researching and analyzing their role in society, and understanding the subject matter and quality of the information content of social networks is becoming urgent. Consideration of this topic at the stage of the regulation of Ukrainian legislation regarding the territorial organization of local authorities will make it possible both to consider in greater detail the system of administrative and territorial division of the State and to identify the main aspects of the use of the information space for communication both within the community and with other external participants in the Internet dialogue.

2 Modern Ways and Tools of Communication in the Community

The advancement of technology has revolutionized the way people communicate in the modern world. With the rise of the internet, people can now connect with each other globally through various online platforms. In this academic text, we will discuss the modern ways and tools of communication in the online community:

- Social media has become an essential tool for communication in the modern era. Platforms such as Facebook, Twitter, Instagram, and LinkedIn enable users to connect with friends, family, colleagues, and even strangers worldwide. These platforms allow users to share their thoughts, feelings, and experiences through text, photos, and videos. They also offer features such as live streaming, private messaging, and group chats, making communication more accessible and convenient.
- Video conferencing has become a popular way of communication in recent years, particularly in the business world. Tools such as Zoom, Skype, and Google Meet allow users to hold virtual meetings with individuals or groups from any location worldwide. Video conferencing enables participants to communicate in real-time, share screens, and collaborate on projects, making it an effective tool for remote work.
- Instant messaging is a real-time communication tool that has been around for many years. However, with the introduction of smartphones, instant messaging has become more popular than ever. Platforms such as WhatsApp, Messenger, and Telegram offer instant messaging services that allow users to exchange text messages, voice messages, photos, and videos with each other. These platforms also offer group chats, making it easier for users to communicate with multiple people simultaneously.
- Email has been around for several decades, and it remains a popular tool for communication in the modern era. Email offers a convenient way to send messages, files, and documents to individuals or groups worldwide. It also allows users to organize their communications and prioritize their messages, making it an effective tool for business and personal communication.

The modern era has brought about various ways and tools of communication in the online community. Social media, video conferencing, instant messaging, and email have become popular tools for communication globally. These tools offer convenience, accessibility, and real-time communication, making it easier for people to connect with each other worldwide.

Nowadays, with the development of modern technologies and the Internet, new opportunities have arisen for information exchange and efficient communication. The development of information and communication technologies contributes to the modernization of the local content of the information space. This state of affairs leads to the expansion of the traditional set of communication channels. Along with the usual forms of direct communication between citizens and local bodies (such as regional and district newspapers, bulletin boards, personal live communication (village gatherings), telephone communication, etc.), the development and implementation of modern forms of communication via the Internet are relevant. They, unlike traditional methods of communication, allow one to react quickly and promptly to a problem and to receive effective feedback.

Modern forms of communication are those digital technologies that provide long-term channels of communication, enable the rapid search for and dissemination of

information, and allow you to promptly exchange ideas, and proposals, to draw on positive experiences for personal progress.

At present, it has been established, that the concept of information technology has emerged with the advent of the information society, where the basis of social dynamics is not the traditional, material resources, but the intellectual ones, such as knowledge, science, organizational factors, people's intellectual ability, initiative, and creativity. For the first time, the concept and prospects of information technology were analyzed in detail by the academician V. Glushkov, who defined information technology as human–machine technology for the collection, processing, and transmission of information.

Information technologies shall include all technologies used for the creation, storage, exchange, and use of information in all possible forms [4]. The term of "information and telecommunication technologies" is used as well, which according to N. Kiyanovska, is based on the use of personal computers, computer networks, and communications and is a more general term, emphasizing the role of unified technologies, integration of telecommunications (telephone lines, wireless connections), computers, software, storage, and audiovisual systems that allow users to create, store, modify, and transmit data to other users.

Information and Telecommunication Technologies (ICT) refer to the use of digital technologies to create, process, store, and exchange information through various forms of communication. It involves the use of electronic devices such as computers, smartphones, tablets, and other digital communication devices, as well as software, networks, and communication technologies like the internet, Wi-Fi, Bluetooth, and other wireless communication protocols.

Information and telecommunication technologies has revolutionized the way we communicate, work, learn, and access information. It has enabled faster and more efficient communication across geographical boundaries, improved data storage and retrieval, and has facilitated the automation of various processes in various sectors such as healthcare, education, manufacturing, and finance.

Information and telecommunication technologies has also led to the creation of new industries, such as e-commerce, software development, and digital marketing, providing new opportunities for employment and economic growth. The continuous advancement of ICT has allowed for the development of innovative technologies such as virtual reality, artificial intelligence, blockchain, and the Internet of Things (IoT), which have the potential to further revolutionize the way we live and work.

Information and telecommunication technologies is a broad term that encompasses a range of digital technologies and communication tools that enable the creation, processing, storage, and exchange of information, transforming the way we communicate and conduct business.

It can be argued that information and communication technologies have become the factor that drastically influences the development of modern society, drives its progress, and provides opportunities to create digital platforms for comprehensive communication.

Information and communication technologies can and are gradually becoming particularly effective in the Ukrainian day-to-day realities. The State's policy of

decentralization and the gradual establishment of territorial communities as separate entities of the new State territorial gradation pose new challenges to the latter. And it is the information space as a set of information infrastructure and entities that collect, form, disseminate, and use information; the system of regulation of relevant public relations [5] will help to solve the tasks, providing the necessary information to residents and communities. At the same time, social networking, as a unique component of the information space, is an excellent platform for the consolidation of citizens according to the similarities of their needs and interests. Social networking is a service that supports social networking on the Internet. An important element of a social network is content (subject matter, information) created by users [6]. There are a large number of social networks that can be classified according to different characteristics.

The following types of social networks can be distinguished by accessibility: closed; open; mixed. Today, most social networks are completely open to everyone.

Geographically: global impact country; individual country; territorial unit; no regional affiliation.

By areas of activity, social networks can be subdivided into personal, professional, and thematic networks. Personal networks are designed to support and improve existing contacts and to find new ones. Professional networks are geared towards professional development and career development. Thematic networks bring audiences together for specific interests: music, politics, science, etc. [7].

That is, social networks have become a tool that has a specific purpose. For united communities, this purpose is "communication with its residents beyond live communication and communication with the world: guests and tourists, investors and business partners, experts and international projects, friendly communities from all over Ukraine and the world" [6].

Such a consolidation leads to the interpenetration of everyday social reality and the virtual one. Against the background of a combination of information and new social technologies, social networks enable citizens and emerging civil society to achieve more efficient and faster communication. This increases the resources for control over government agencies and individual officials, and enhances the chances of implementing public initiatives. Online communication leads to increased public engagement and decision-making, and the ability to communicate with the authorities becomes an important indicator of the effectiveness of public administration [8].

In recent years, there has been an increase in the interest of the scientific community in the reasons for decentralization in Ukraine, it is featured, and priority orientations. Thus, the Italian researcher F. Palermo in his work raised the issue of understanding by the Ukrainian people of such key concepts as "autonomy", and "separation" and noted that the implementation of decentralization is a positive step towards the democratization of society and the state [9]. The majority of authors [10, 11] see the main objective of their scientific work in the analysis of the process of state search for new ways to solve problems of governance at the district and regional levels and the role of the experience of leading Western European countries in this. Researchers offer their own vision for solving pressing problems and offer options

for outlining future changes to the current legislation of Ukraine on public administration at the district and regional levels. Only a small number of scientists are actually studying the impact of decentralization on the changes in the development of the regions and the newly unified territorial communities (UTCs). Thus, Halhash et al. [12], Serohina et al. [13] focus on studying foreign experience in the reform of the administrative and territorial system and prove that since the beginning of the reform Ukraine has stepped up its processes, which provide for the participation of citizens in the management and positive development of the regions.

Of great importance regarding the research on the use of digital technologies in the activities and territorial communities in particular is the scientific study by I. Davydova, O. Bernaz-Lukavetska, S. Reznichenko, who drew attention to the long-standing problem of personal data protection in Ukraine. The authors noted that under the new administrative arrangements, the active expansion of the information space, and the rapid involvement of a growing number of people in this area, there was an urgent need to harmonize the Ukrainian domestic legislation in line with EU legislation; which should lead to the creation of a new law on the protection of personal data that will meet European standards [14].

For their part, A. Kutsyk and V. Golovei in their article [15] considered the role and importance of social networks in the process of the formation of civil society in Ukraine, analyzing the positive and negative influences of social networks on political life. The authors noted that, in addition to various sociocultural and communicative functions, social media had become a catalyst for political change and a platform for active social participation. The impact of social media on state processes is significant, which is manifested in the active promotion of new practices of public participation, consolidation, and self-organization of the Ukrainian civil society. They justified the future growing role of social networks as an important factor in the development of civil society in the context of democratic media policy.

As the analysis of recent scientific studies shows, the authors focus mainly on their own implementation of the decentralization process and the formation of new legal and regulatory relations. The role of digital technology is negligible, although individual scholars are somewhat concerned with the issue. However, to date, the use of social media as a means of communication in society has not yet been the subject of a separate scientific study.

The role of social networks in different contexts has been also considered by scientists [16–19]. The emergence of social networks has had a profound impact on the way people communicate and interact with each other. With millions of people using social networking sites on a daily basis, these platforms have become an integral part of people's lives, influencing their attitudes, behaviors, and relationships. This paper examines the role of social networks in different contexts [20, 21], including personal, professional, and educational settings.

In personal contexts, social networks have enabled people to connect with friends and family, share personal experiences, and engage in online communities. With the ease of access to social networking sites, people can keep in touch with loved ones regardless of distance and time constraints. The use of social networks has also

facilitated the formation of new friendships, providing individuals with opportunities to expand their social circles and meet new people.

In professional contexts, social networks have become a valuable tool for networking and career development. Through social networks, individuals can establish and maintain professional connections, share information, and collaborate on projects. Social networks such as LinkedIn have become an essential resource for job seekers, allowing them to showcase their skills, experience, and achievements to potential employers.

In educational contexts, social networks have become an important platform for communication and collaboration among students and teachers. Social networks allow students to connect with their peers, share educational resources, and discuss academic topics. Teachers can use social networks to communicate with their students, provide feedback, and facilitate group discussions.

Despite the benefits of social networks, there are also potential risks and challenges associated with their use. Social networks [22–25] lead to cyberbullying, privacy breaches, and addiction. It is essential for users to be aware of the risks and to take appropriate measures to protect themselves.

In conclusion, social networks have become a ubiquitous part of modern society, playing a significant role in personal, professional, and educational contexts.

The impact of social networks on society is complex, and there are both advantages and risks associated with their use. It is crucial for individuals to understand these complexities and to use social networks in a responsible and ethical manner.

2.1 Practical Aspects of Using Social Networks in the Communication Activity of the Community

The present dictates new rules for conducting information and communication activities within the community. Quality representation of united territorial communities on the Internet is important. In particular, not limited to information on the website of the territorial community, communities are actively developing publicity on social networks as a modern communication tool.

Social networks are an open information environment, the main task of which is to exchange information both within the community and about the community as a whole. In this context, it is important and necessary to acquire the skills to effectively use their potential. Thanks to the "U-LEAD with Europe" [26] international program, which supports the Government of Ukraine in implementing the decentralization reform and regional development, and helps communities to develop an effective communication strategy, we have an opportunity to familiarize ourselves with the specially created "Digital Communications in Society" platform and with online courses, which highlight the rules and benefits of using digital tools to build successful internal and external community communication. Statistics show that in Ukraine, approximately 25 million people use the Internet every day, and 64% of them use

social networks. These figures once again confirm that social networks are a powerful resource for communication.

Among popular social networks in Ukraine, we can distinguish Facebook (a platform that allows you to post photos, videos, text posts, and online broadcasts), Instagram (a service for publishing and discussing photos and videos), Twitter (a service for publishing short public messages) and YouTube video hosting (allows you to post a video and accompany it with comments). These are the fastest, easiest, and most democratic channels for distributing content to community members. They are effective channels of coverage of its cultural and everyday life. Their proper use, understanding of the technical features of creating accounts, their content, promotion, increasing user reach, and rules that will help gather the target audience, will help to establish better communication with the community.

The most popular social network is Facebook. In Ukraine, 13 million people are using it. This number is constantly increasing. According to its technical capabilities, the network allows each user to create three types of pages: a private profile, a public page, and a theme group. Among these three types of community accounts, the most functional is the public page which has more opportunities to popularize the community and disseminate information. When creating a community account, it is necessary to define its name briefly and clearly.

The main photograph (avatar—the logo of the community) should be clear and display something remarkable and defining, which will help to form an image of the community. Available group examples/community pages show that, as a rule, symbolic images, such as the coat of arms of the community, are selected for the main photograph and the background (cover). It is also common to use images of the main office building or to make collages of various photographs illustrating the daily and festive life of the local residents.

At the stage of filling in a new account, it is necessary to enter contact and organizational information, such as an address, location map, contact phone, link to the site, and office hours. In addition, general information should be provided on the community (administrative center, total area, population, and composition of the community) and its team. Such information may include short quotations and comments, photographs, and other additional information. This will help users to learn about the core and to better understand the professional structure of the institution.

When maintaining a page/group, it is important to work with content, which requires regular coverage of new information and the creation of posts. Particular attention should be paid to the wording of the title of the post. It should get the user interested, and encourage him to open the page and read the entire text. Facebook is a platform that allows you to post photos, videos, and text messages and conduct online broadcasts. You need to keep your page creative and interesting, so that your posts are covered and appear in the news feed of as many users as possible.

The rule that needs to be followed and that will help you achieve this is to produce quality content. At the initial stage of maintaining the page, it will be enough to post two or three posts a day: if there are more, they will be lost in the news feed.

The appearance of the post in the news feed is determined by the correct algorithms for writing posts and the activity of the administrator (moderator) of the page. It is recommended to make more often materials with photos, with references to sources and experts' comments. If the content of the post is interesting and presented in a creative way, users respond to it (share it, comment, view videos and photos), thus increasing its coverage and subsequent posts appear in the feed of more users. This is "organic coverage—people visit your page because you are interesting". It is worth noting that thematic groups have better organic coverage than public pages, they also maintain closer contact with the target audience [23].

2.2 Communication Functionality for Society Through the Use of Facebook Social Network

Active use of social networks significantly increases the functionality of communication for the community. Being widely known in society as an important communication tool, they cover the life of the community, help explain the decisions made by the authorities, and involve citizens in the development of a small territory. In addition, social networks contribute to the establishment of external channels of communication. First of all, it includes the need to establish contacts with tourists, and cooperation with investors, business partners, experts, and other communities from all over Ukraine and the world, to join international projects. By taking advantage of the Facebook network, the community is able to provide free, quick, and instantaneous coverage of important public events and provide reliable information about itself with no middlemen involved [23]. Considering the high rate of activity of users on the Facebook social network, we will single out its functionality:

- disclosure and dissemination of information about events that have taken place or are planned in the future;
- announcement and coverage of news;
- implementation of local initiatives related to community needs (public space planning, etc.);
- involvement of community residents in the discussion and submission of proposals on a particular initiative;
- invitation of those interested to implement the set goal;
- follow up on the results of the survey and the number of people who responded to the invitation and will join in the implementation of the project, thus making it possible to assess the prospects and level of implementation of the planned work.

Facebook also allows you to create different communication campaigns for various needs that arise in society. For example, calling people on a Saturday to clean up the area that is common to the locals. Thus, Dzhulyn United Territorial Community (Vinnytsia region), has Facebook pages, the official page of the community, "Dzhulyn Territorial Community", and the public group "Dzhulinchany" (created

in 2017, has more than 3,000 subscribers, which is designed to communicate with everyone who is interested in the history and present of Dzhulynka, and generally monitors the development of the community), through a message informs its residents about the need to support the municipal improvement of the community.

In general, the proper appearance of the community's settlements is the responsibility of the administration of the Dzhulyn United Territorial Community, in particular, the employees of the Department of Education, Culture, and Sport, who are actively using this communication platform.

The Department coordinates the main issues of the sociocultural life of the society. For example, they install, decorate and maintain wooden roadside crosses with brick foundations. Before the Easter holidays, thanks to the ideas of the local authorities, to which the local people usually respond rather actively, the need to clean and decorate the old cemetery was initiated and communicated [27].

The communication specialist of the Swiss-Ukrainian Decentralization Support Project DESPRO G. Osadcha reveals in her research the potential of social networks as a convenient tool of communication of the community with the elder. Developing this topic, the researcher notes that by having his own public page, the elder can easily establish communication with his fellow elders of other communities. The public page of the elder can become a virtual platform for an exchange of views, opinions, the statement of the general public on a particular issue or situation [6].

Moreover, the positive experience of direct requests (that is the possibility to ask a question directly), to address the leadership of the united territorial community (the head of the united territorial community or the elder of the community) with different questions, such as the celebration of the Village Day, road repairs, reconstruction of street lighting, culture, and art center redecoration, etc., reduces traffic in the reception area of the head.

Apart from it, receiving feedback from management reduces the tension in solving a problem, and prevents misunderstandings and the dissemination of false information. Such quick communication makes it possible to immediately get an answer and to understand what plans have already been developed by the community leadership.

At the same time, there is a gradual trend of a number of Facebook users outflow (primarily young people) and an increase in the number of users of such platforms as TikTok, Telegram, and Instagram. This can be explained by the creativity and compactness of the latter.

The fact is that these social networks do not require writing large text messages, but are aimed at using photos and editing videos, which create and convey information much faster than they would when using textual means.

Therefore, it is necessary to highlight both the advantages and disadvantages of using the Facebook network (Fig. 1) [28].

The pros and cons of using Facebook are shown in Tables 1 and 2.

It's important to note that the impact of Facebook use can vary greatly from person to person, and the pros and cons listed above are not exhaustive. It's up to each individual to weigh these factors and determine whether or not using Facebook aligns with their personal values and goals.

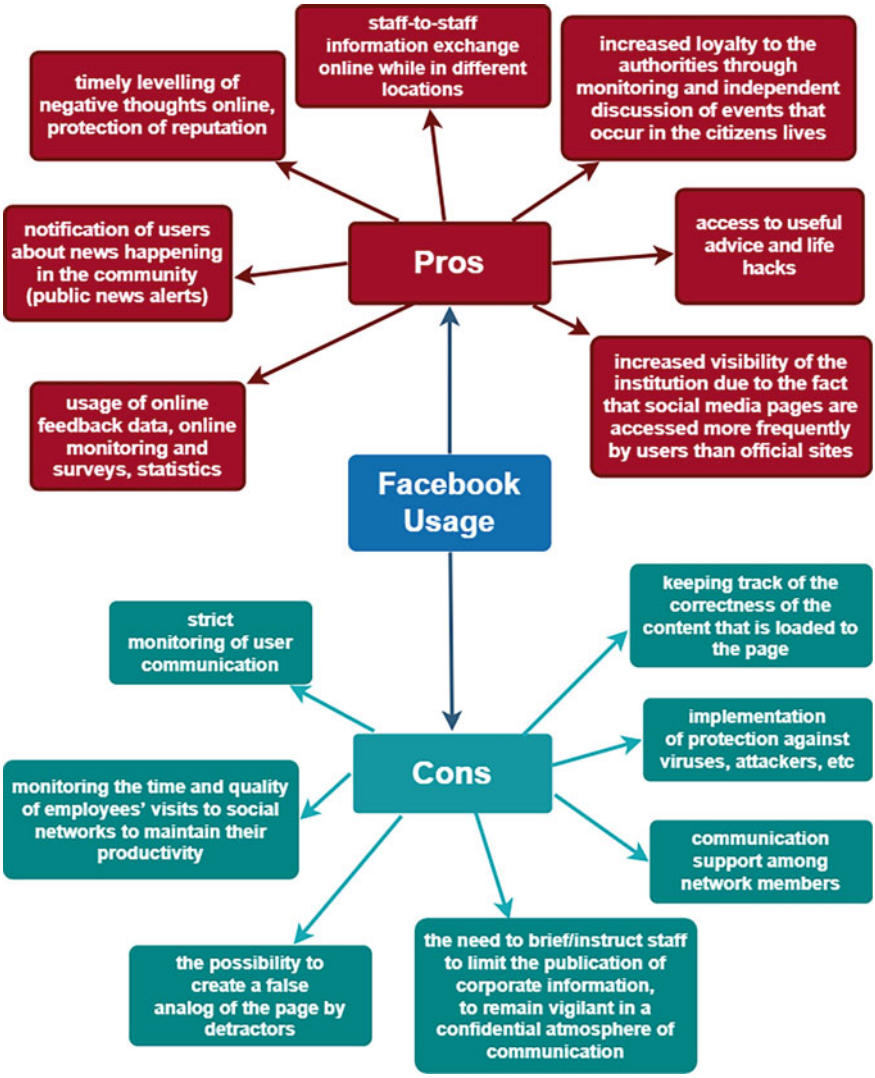


Fig. 1 Pros and Cons of using Facebook

2.3 Communication Activity of Communities in the Facebook Network

As part of the study, we analyzed the presence of a public page and/or thematic community group on Facebook in the example of the Vinnytsia region. Data on all aspects of the decentralization process in Ukraine and the created united territorial

Table 1 The pros of using Facebook

Pros	Explanations
Helps to stay connected with friends and family	Facebook allows users to easily connect with their loved ones who may live far away or who they don't get to see very often. This can help maintain and strengthen relationships
Provides a platform for businesses to reach potential customers	Facebook's advertising tools allow businesses to target potential customers based on demographics, interests, and behaviors. This can help businesses expand their reach and generate more sales
Offers a range of features like groups, events, and marketplace	Facebook provides a variety of features that allow users to engage with each other and the platform in different ways. Groups, events, and marketplace all serve different purposes and can provide value to users
Can help in finding and joining communities with shared interests	Facebook's groups feature allows users to join communities based on shared interests, hobbies, or causes. This can help users find like-minded people and engage with others who share their passions
Allows sharing and discovering of news, articles, and entertainment content	Facebook's news feed allows users to discover and share content with their friends and followers. This can help users stay up-to-date on current events, discover new information, and be entertained
Can be used for networking and professional opportunities	Facebook can be a valuable tool for networking and finding professional opportunities. Users can join industry-specific groups, connect with other professionals, and showcase their work or skills on their profiles
Offers a convenient way to organize and RSVP to events	Facebook's events feature allows users to easily organize and RSVP to events. This can be especially helpful for large or public events where keeping track of attendees can be difficult
Can be used for charity and fundraising efforts	Facebook provides tools for users to create fundraisers and donate to charities. This can help raise awareness for important causes and generate donations

communities as of 2020 can be obtained on a special Internet portal, called "Decentralization provides opportunities" [29]. Based on the results of the analysis, we can state that out of 63 united territorial communities, 15 communities have a page and a group, 32 communities—have only a group, 13 communities—have only a page, 3—have a page dedicated to the village/urban-type settlement council, being the center of the united community (Fig. 2).

Table 2 The cons of using Facebook

Cons	Explanations
Can lead to addiction and time-wasting	Facebook can be addictive and can lead to users spending excessive amounts of time scrolling through their news feed. This can negatively impact productivity, mental health, and relationships
Can be a source of misinformation and fake news	Facebook has been criticized for its role in spreading misinformation and fake news. Users may be exposed to false information or propaganda that can impact their beliefs or behaviors
May compromise privacy and personal information	Facebook has faced numerous controversies regarding user data privacy. Users may unknowingly share personal information or have their data collected by third-party apps or advertisers
May negatively impact mental health and self-esteem	Studies have shown that social media use, including Facebook, can negatively impact mental health and self-esteem. Users may feel pressure to present a perfect image of their lives or compare themselves to others, leading to feelings of inadequacy or anxiety
May promote cyberbullying and harassment	Facebook can be used as a platform for cyberbullying and harassment, especially among younger users. This can lead to emotional distress and even harm to one's reputation or safety
May contribute to political polarization and societal division	Facebook's algorithms can create filter bubbles, where users are only exposed to content that aligns with their existing beliefs and opinions. This can contribute to political polarization and societal division
May cause feelings of FOMO (fear of missing out) and anxiety	Users may feel pressure to constantly check Facebook to stay up-to-date on their friends' activities or events. This can lead to feelings of FOMO and anxiety about missing out on important experiences
May result in a loss of productivity and creativity	Excessive Facebook use can lead to a loss of productivity

Hereof it follows, that the largest number of united territorial communities have created a thematic group (50%), more than 25% represent their community through the official page, and almost 20% have both a page and a group, less than 5% are communities that are on Facebook created a page of the village/urban-type settlement council (Fig. 3).

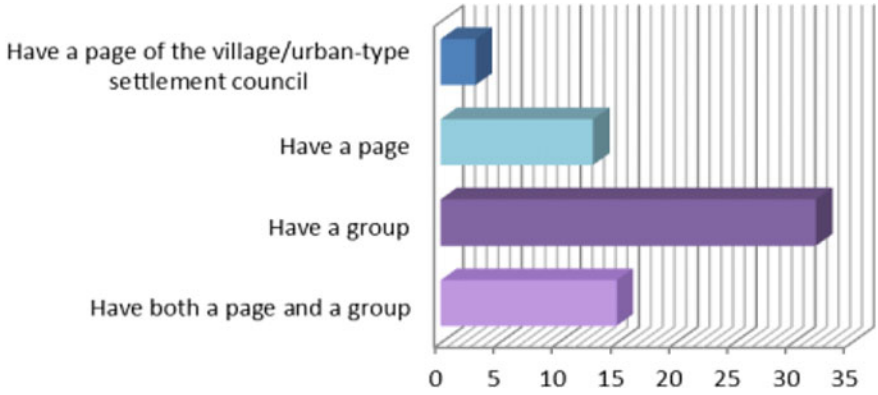


Fig. 2 The quantification of the territorial communities of Vinnytsia region representation on Facebook

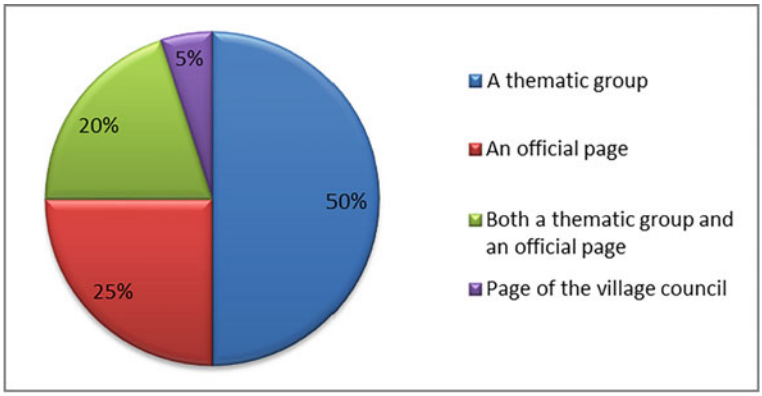


Fig. 3 The percentage ratio of the territorial communities of Vinnytsia region representation on Facebook

It is worth noting that the united territorial communities of the Vinnytsia region additionally have other thematic groups in different areas of activity. For example, there are pages of public organizations (NGO "Viche Hromady"—Yakushynets' UTC), educational institutions (Municipal institution "Yakushinetsky lyceum", Vendychansk Secondary School of I-III levels, a gymnasium, Luka-Meleshkivska Children's School of Arts), libraries (Vendychansk settlement public library), Centres for the Delivery of Administrative Services (Hnivan CDAS, Department of Education of Hnivan City Council, Public Control of Yakushinets' UTC", and news coverages ("Barski Visti" (Bar News), "Bershadski Visti" (Bershad News), "Haisyn Visti" (Haisyn News), etc.).

Having analyzed the content on the pages of the united territorial communities in Vinnytsia region, it is indicative that the most popular are the posts about

solving communal and household problems (landscaping and public amenities issues, purchase and sale advertisements, job search, garbage collection), the need for assistance in the treatment of compatriots, congratulations on state or religious holidays, holding festive events (opening of historical monuments, etc.), encouragement of active residents of the community, etc. The posts tend to be accompanied by photos rather than by videos.

In addition to the quantitative representation of communities on the Facebook social network, an important factor for our research was the audience activity on the page/in the Facebook group. Three territorial communities of the Vinnytsia region, which belong to the category of urban communities, formed by a merger with a town, were selected for our analysis. It was stipulated by the fact that people in rural areas probably use the Internet less for different reasons than urban residents. One such reason is that, unfortunately, the state of internet-connectedness today remains quite low in Ukraine. This is especially noticeable in low-lying areas and areas with forest belts, on roads, and at points along the railway tracks. In these places, the Internet connection allows you to use mobile communication only for voice calls (2G), and in some places, the Internet service is unavailable at all.

The authors of the article determined the level of activity of users/participants on the page / in the Facebook group according to the following criteria:

1. Audience involvement—the number of subscribers in relation to the population of the community.
2. Publication activity—the number of posts per day/month.
3. Activity of users (subscribers) on the page/in the group—a set of reactions to the publication (number of "likes", comments, reposts).
4. Feedback—the presence of a feedback button (quick access).

After analyzing the pages/groups of urban united territorial communities of the Vinnytsia region by the criterion of involvement, we conclude that this indicator is radically different in different urban UTCs. Thus, the highest percentage of subscribers per page/group was 38.4% (7,234 subscribers with a population of 18,834), and the lowest was 0.5% (221 subscribers with a population of 43,159). That is, compared to the population of the community, the level of audience involvement (number of page subscribers/group members) should be increased. There is, however, a positive trend, as new members are added on a daily basis and their number is steadily increasing.

Based on the results of the research of publishing activity on Facebook pages / in groups of the urban united territorial communities in the Vinnytsia region, we obtained data confirming the high rate of presence of messages on the page / in the group of the local community. Their characteristic feature is the frequency of publications (on average 3–5 communications per day).

The activity of subscribers is also low, as evidenced by the small number of comments, reposts, and likes published under the posts. After reviewing the intensity of the audience's response to existing posts, it was found, that most publications received the following reaction: 131 comments, 690 likes, and 291 reposts.

The "Feedback" indicator should be considered in light of the fact that the pages created by communities (six out of the selected list of urban communities), as opposed to groups on Facebook, have a quick access button (feedback button) through "Contact us" or "Send us a message" options.

While comparing the capabilities and advantages of social media and the community website, first and foremost, we observe a striking difference in the target audience. The target audience of the community site is the active part of its residents (opinion leaders, politicians, activists, journalists, managers, investors, and tourists). These are the categories of people, who use the information from the community site the most. The target audience of Facebook is larger. After all, in addition to activists and politicians, it has more followers, who are 25 years of age or older. Instagram users are young people and children. So, given the above, the community's public Facebook page is a channel of communication with a large audience of residents, while the Instagram network provides an opportunity to strengthen communication with active youth [30, 31].

Facebook is one of the most powerful and influential social media platforms in the world [32], with over 2.8 billion active users as of 2021. Its strength lies in several key areas:

- User Engagement: Facebook has created a highly addictive platform that keeps users engaged for extended periods of time. Its user-friendly interface, personalized news feeds, and algorithmic recommendations make it easy for users to find and consume content that is relevant to their interests.
- Advertising: Facebook's advertising platform is one of the most sophisticated in the world, allowing businesses to target specific demographics and interests with pinpoint accuracy. This has made it a highly effective tool for marketers looking to reach their target audience.
- Data Collection: Facebook collects vast amounts of data on its users, including their demographic information, browsing behavior, and interests. This data is incredibly valuable to marketers and advertisers, who use it to create highly targeted campaigns.
- Integration: Facebook has integrated with a wide range of other apps and services, making it an essential part of many people's online experience. This integration has helped to strengthen its position as a dominant player in the tech industry.

Facebook's strength lies in its ability to engage users, collect data, and provide advertisers with highly targeted advertising opportunities. As long as it continues to innovate and adapt to changes in the industry, it is likely to remain a dominant force in the social media landscape.

Instagram is one of the most popular social media platforms in the world [33], with over 1 billion monthly active users. Its strength lies in several factors:

- Visual content: Instagram is primarily a photo and video-sharing platform, which makes it a great platform for visual storytelling. Users can share high-quality photos and videos, edit them with filters and other tools, and showcase their creativity and personality.

- Engaging features: Instagram has a range of features that keep users engaged, including Instagram Stories, Reels, IGTV, and Live videos. These features allow users to share their experiences in real-time and connect with their followers on a more personal level.
- Influencer culture: Instagram has a thriving influencer culture, with millions of users using the platform to build their personal brands and connect with their followers. Influencers can partner with brands and promote products, and in turn, create a lucrative income stream.
- Community: Instagram fosters a strong sense of community, with users connecting with like-minded people through hashtags and shared interests. Users can also create private groups and connect with friends and family in a more intimate setting.
- Mobile-first: Instagram is designed for mobile devices, which makes it easily accessible to users on-the-go. Its mobile-first design and intuitive interface make it easy for users to create and consume content quickly and efficiently.

Instagram's strength lies in its ability to provide a visually engaging and social platform that allows users to connect with others and showcase their creativity and personality.

The main aspects of the analysis of social networks [21, 22] are the following:

- Audience Size
- Engagement
- Demographics
- Content Types
- Posting Frequency
- Influencers
- Conversion Rate
- ROI

The result of the analysis of social networks is shown in Table 3.

Based on the analysis of social networks using the various metrics mentioned in Table 3, we can conclude that a social network's audience size is a significant factor in determining its reach. Engagement metrics like likes, comments, and shares per post provide an indication of audience interaction and interest, which help gauge the effectiveness of content strategies. Demographic analysis of the audience target specific segments for marketing and content creation. Content type analysis helps inform content creation and posting strategies. Posting frequency affects audience engagement and reach. Influencers can increase a profile's visibility and credibility. The conversion rate measures the effectiveness of the social network as a marketing channel, and the return on investment (ROI) indicates the financial success of social network marketing campaigns. Therefore, to optimize the effectiveness of social network marketing campaigns, it's crucial to analyze all these factors and use the insights gained to inform marketing strategies.

Table 3 The result of the analysis of social networks

Aspect of Analysis	Metrics	Example Calculation	Interpretation
Audience Size	Number of followers/ subscribers	10,000	Indicates the reach of the social network
Engagement	Likes, comments, shares, retweets, etc	500 likes per post	Indicates the level of audience interaction and interest
Demographics	Age, gender, location, etc	60% female, 40% male	Can help target specific audience segments for marketing or content creation
Content Types	Text, images, videos, etc	60% images, 30% videos, 10% text	Can inform content creation and posting strategies
Posting Frequency	Number of posts per day/week/month	3 posts per day	Can affect audience engagement and reach
Influencers	Number of influential accounts following or engaging with the profile	5 influencers with over 100,000 followers each	Can increase the profile's visibility and credibility
Conversion Rate	Number of users who take a desired action (e.g. clicking a link, making a purchase)	2% conversion rate on product links	Measures the effectiveness of the social network as a marketing channel
ROI	Return on investment (e.g. revenue generated from social network campaigns)	$10,000 in sales from social media campaigns	Indicates the financial success of the social network as a marketing channel

2.4 Conclusions

The research on modern ways and forms of communication in the territorial community made it possible to define their specifics and rules of use. Digital tools, being modern effective channels of information dissemination, have great potential, if handled skillfully, for the formation of a culture of social trust between the government and the community.

Specific examples of the use of tools of social networks in the formation of the information space of the territorial community show that they justifiably become a special platform for the exchange of views, proposals, and ideas. They demonstrate their potential in providing assistance in strengthening the activity of community residents in decision-making, gaining a qualitatively new level of public service, and organizing information campaigns. The active use of the Internet, including social networks, by local authorities (the head of the united territorial community, the elder of the community) provides ample communication opportunities for communication both within the settlement and outside it.

After analyzing the level of activity of the audience on the page / in the group Facebook, we noted the high rate of publishing activity. The posts are regular and in sufficient numbers. At the same time, it is significant that communities are not taking full advantage of Facebook. The level of outreach (number of subscribers), user activity (response to messages), and feedback need to be increased. This can be achieved by expanding the subject and improving the quality of information content, as well as working to increase organic coverage. Of course, we assume that one of the reasons for the low activity of users is the objective circumstances—the lack of access to the Internet in rural areas. However, the analysis of the information content of the page/group (the available posts are mainly related to solving household and communal issues) confirms the need to expand the content.

The reason is that social networks, as virtual communication platforms with great potential, can be used in a much wider range of development of a small area: for the development of tourism in the region, the disclosure of its sociocultural "baggage" and so on. Popularization of the historical heritage of the region, its cultural traditions, and outstanding achievements, would contribute to the formation of the image of a small territory, which would provide an opportunity to attract tourists and attract investment.

References

1. About local self-government in Ukraine. Law of Ukraine as of 21/05/1997 № 280/97-BP. https://zakon.rada.gov.ua/laws/show/280/97-%D0%B2%D1%80#Text
2. About formation and liquidation of areas. Resolution of the Verkhovna Rada of Ukraine as of 17/07/2020 № 807-IX. https://zakon.rada.gov.ua/laws/show/807-20#Text
3. About formation of territorial communities (2020). https://decentralization.gov.ua/gromadas**.**
4. Kianovska, N.: Genesis of the concept "Information and telecommunication technologies." Proceedings. Series: Pedagogical Sci. **1**(121), 117–122 (2013)
5. Glazova, Ya.: Analysis of the structure and components of the information space of territorial community. Visnyk of Zaporizhzhya Nat. Univ. Econ. Sci. **1**, 42–52 (2016)
6. Osadcha, H.: Social networks as a convenient communication tool for elders and communities (2019). https://i.factor.ua/ukr/journals/rs/2019/september/issue-3/article-70466.html
7. Turchyn, Classification of social networks. Proceedings of the All-Ukrainian scientific-practical conference, Current challenges and achievements in the field of cybersecurity, Kropyvnytskyi, p. 206 (2016). https://core.ac.uk/download/pdf/84825408.pdf
8. Chupryna, L.: Social networks as a tool for implementing public initiatives (2016). http://nbuviap.gov.ua/index.php?option=com_content&view=article&id=1085:sotsialni-merezhi-yak-instrument-realizatsiji-gromadskikh-initsiativ&catid=127&Itemid=460
9. Palermo, F.: The elephant in the room: Ukraine between decentralization and conflict. Ethnopolitics **19**(4), 369–382 (2020). https://doi.org/10.1080/17449057.2020.1795473
10. Harust, Y., Durnov, Y., Boichuk, A., Chernezhenko, O., Holosnichenko, I.: Administrative-territorial reform: the experience of the countries of Western Europe. Cuestiones politicas **37**(65), 248–267 (2020). https://doi.org/10.46398/cuestpol.3865.19
11. Semigina, T., Maidannyk, O., Onischyk, Y., Zhuravel, Y.: Local self-government reforms in Europe: legal aspects of considering the communities' social identity. Juridical tribune **10**(2), 207–221 (2020). https://doaj.org/toc/2248-0382
12. Halhash, R., Semenenko, I., Bilous, Y., Burko, I.: Impact of decentralization on sustainable development of the newly created amalgamated territorial communities in the regions

of Ukraine. Europ. J. Sustain. Dev. **9**(1), 19–33 (2020). https://doi.org/10.14207/ejsd.2020.v9n1p19
13. Serohina, S., Bodrova, I., Novak, A.: Delegation of state powers to local self-government bodies: foreign experience and Ukrainian realities. Baltic J. Europ. Studies **9**(3), 262–285 (2019). https://doi.org/10.1515/bjes-2019-0033
14. Davydova, Bernaz-Lukavetska, O., Reznichenko, S.: Certain aspects of personal data protection in the social network: European experience and legislative regulation in Ukraine. Amazonia Investiga **9**(27), 383–390 (2020). https://doi.org/10.34069/AI/2020.27.03.42
15. Kutsyk, Golovei, V.: Social networks as a factor in the development of civil society in Ukraine. Europ. J. Tranf. Studies **8**(1), 109–125 (2020)
16. Anisimova, O., Vasylenko, V., Fedushko, S.: Social networks as a tool for a higher education institution image creation. CEUR workshop proceedings. 2019. Vol 2392: Proceedings of the 1st International Workshop on Control, Optimization and Analytical Processing of Social Networks (COAPSN-2019), pp. 54–65. http://ceur-ws.org/Vol-2392/paper5.pdf
17. Rahaman, M.: Addiction of information and communication technology (ICT) and internet by the Bangladeshi university students and its impact on their future. Int. J. Inf. Technol. Comput. Sci. (IJITCS) **10**(8), 56–68 (2018). https://doi.org/10.5815/ijitcs.2018.08.08
18. Molodetska, Brodskiy, Yu., Fedushko, S.: Model of assessment of information-psychological influence in social networking services based on information insurance. In: CEUR Workshop Proceedings, volume 2616: Proceedings of the 2nd International Workshop on Control, Optimization and Analytical Processing of Social Networks (COAPSN-2020), Lviv, Ukraine, pp. 187–198 (2020). http://ceur-ws.org/Vol-2616/paper16.pdf
19. Mukhin, V., Romanenkov, Yu., Bilokin, J., Rohovyi, A., Kharazii, A., Kosenko, V., Kosenko, N., Su, J.: The method of variant synthesis of information and communication network structures on the basis of the graph and set-theoretical models. Int. J. Intell. Syst. Appl. (IJISA) **9**(11), 42–51 (2017). https://doi.org/10.5815/ijisa.2017.11.06
20. D'Andrea, A., Ferri, F., Grifoni, P.: An Overview of Methods for Virtual Social Networks Analysis, pp. 2–35. Springer, London (2010)
21. Freeman, L.: The development of social network analysis. Study Soc. Sci. **1**(687), 159–167 (2004)
22. O'malley, A.J., Marsden, P.V.: The analysis of social networks. Health Serv. Outcomes Res. Methodol. **8**, 222–269 (2008)
23. Hu, Z., Odarchenko, R., Gnatyuk, S., Zaliskyi, M., Chaplits, A., Bondar, S., Borovik, V.: Statistical techniques for detecting cyberattacks on computer networks based on an analysis of abnormal traffic behavior. Int. J. Comput. Netw. Inf. Secur. (IJCNIS) **12**(6), 1–13 (2020). https://doi.org/10.5815/ijcnis.2020.06.01
24. Hu, Zh., Khokhlachova, Yu., Sydorenko, V., Opirskyy, I.: Method for optimization of information security systems behavior under conditions of influences. Int. J. Intell. Syst. Appl. (IJISA) **9**(12,) 46–58 (2017). https://doi.org/10.5815/ijisa.2017.12.05
25. Hu, Z., Tereykovskiy, I., Tereykovska, L., Pogorelov, V.: Determination of structural parameters of multilayer perceptron designed to estimate parameters of technical systems. Int. J. Intell. Syst. Appl. (IJISA) **9**(10), 57–62 (2017). https://doi.org/10.5815/ijisa.2017.10.07
26. U-LEAD with Europe. https://u-lead.org.ua/
27. Digital Communications in the Community: Online Course (2019). https://u-learn.org.ua/courses/digital-communications/lectures/12038567
28. Horova, V.: Ukrainian community in the context of global challenges: social and cultural aspects of decentralization. In: Ethnocultural Transformations in the Ukrainian Modern System, IMFE Publishing House, Kyiv, pp. 19–33 (2019)
29. Stupnytska, Ya.: The use of social networks to inform the population by local governments of Rivne region (2013). https://naub.oa.edu.ua/2013/vykorystannya-sotsialnyh-merezh-dlya-informuvannya-naselennya-orhanamy-mistsevoho-samovryaduvannya-rivnenschyny
30. Decentralization provides opportunities. https://decentralization.gov.ua/newgromada
31. The use of digital tools in united territorial communities. Digital communication matrix (2019). https://u-learn.org.ua/courses/digital-communications/lectures/12329488

32. Hruska, J., Maresova, P.: Use of social media platforms among adults in the United States—behavior on social media. Societies **10**(1), 27 (2020)
33. Arora, A., Bansal, S., Kandpal, C., Aswani, R., Dwivedi, Y.: Measuring social media influencer index-insights from Facebook, Twitter and Instagram. J. Retail. Consum. Serv. **49**, 86–101 (2019)

Software System for Cybersecurity Events Correlation and Incident Management in Critical Infrastructure

Sergiy Gnatyuk, Rat Berdibayev, Marek Aleksander, Viktoriia Sydorenko, Oksana Zhyharevych, and Artem Polozhentsev

Abstract The current information infrastructure, with its diverse systems and components, demands continuous monitoring and management to detect and respond to potential cyber threats. To mitigate these risks, the deployment of a unified standard system, known as a Security Information and Event Management (SIEM) system, is recommended. This technology, which collects event log data, conducts real-time analysis to identify unusual activity, recognizes potential threats, generates alerts, and suggests appropriate action plans, has seen significant improvements in both quantity and quality due to advancements in artificial intelligence, the Internet of Things, and cloud technologies. These advancements enable the rapid and effective detection of threats. This study focuses on contemporary SIEM systems, exploring their functionality, fundamental operational principles, and conducting a comparative analysis of their capabilities, distinctions, benefits, and drawbacks. Additionally, the study developed and experimentally investigated a universal system for event correlation and cybersecurity incident management in critical infrastructure facilities. The study also introduced hybrid security data storage models that allow the indexing service to access external data storage, scale with increasing data volume, and ensure high search speed. Furthermore, the study developed models, methods, and algorithms for

S. Gnatyuk (✉) · V. Sydorenko · A. Polozhentsev
National Aviation University, Kyiv, Ukraine
e-mail: s.gnatyuk@nau.edu.ua

S. Gnatyuk
Yessenov University, Aktau, Kazakhstan

State Scientific and Research Institute of Cybersecurity Technologies and Information Protection Kyiv, Kyiv, Ukraine

R. Berdibayev
Almaty University of Power Energy and Telecommunication, Almaty, Kazakhstan

M. Aleksander
University of Applied Sciences in Nowy Sącz, Nowy Sącz, Poland

O. Zhyharevych
Lesya Ukrainka Volyn National University, Lutsk, Ukraine

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2024

P. Štarchoň et al. (eds.), *Data-Centric Business and Applications*, Lecture Notes on Data Engineering and Communications Technologies 213,
https://doi.org/10.1007/978-3-031-62213-7_12

operating a distributed data bus that allows high-speed processing of large information flows, minimal latency, high resilience to failures, and flexibility. The proposed system plays a crucial role in addressing numerous cybersecurity issues and aligns with the main requirements of international standards and global best practices for creating cyber incident management systems.

Keywords Incident management · Critical infrastructure objects · Cyber security · Cyber security incident · Critical infrastructure · Cyber threat · SIEM system · Event correlation system

1 Introduction

SIEM (Security Information and Event Management) is a crucial and rapidly advancing area that effectively identifies threats and implements countermeasures to ensure the necessary level of protection for information infrastructure. The SIEM system plays a critical role in the timely collection, storage, and analysis of security event data generated and recorded in the system logs of various hardware and software elements within the information infrastructure, such as servers, workstations, routers, firewalls, database management systems, and antivirus tools. The primary purpose of building and operating SIEM systems is to significantly enhance information security (IS) in the information and telecommunications infrastructure by providing near real-time manipulation of security information and proactive management of security incidents and events. "Proactive" refers to taking action before the situation becomes critical. Proactive management of security incidents and events is based on automatic mechanisms that use information about the history of analyzed network events, forecasts of future events, and automatic adjustment of event monitoring parameters to the current state of the protected system [1, 2]. To achieve this goal, a SIEM system for critical infrastructure (CI) must successfully address the following tasks:

- Collecting, processing, and analyzing security events from various heterogeneous sources.
- Real-time detection of attacks and security policy violations.
- Conducting operational assessments of the security of information, telecommunications, and other critical resources.
- Analyzing and managing CI security risks.
- Investigating security incidents.
- Identifying and resolving discrepancies between critical resources, business processes, and internal security policies.
- Making informed IS decisions.
- Generating comprehensive reporting documents.

To perform these tasks, the SIEM system relies primarily on records from various logs that capture critical infrastructure (CI) events, known as "security events". These events document the actions of users and programs that could impact security. From

the vast pool of security events, the SIEM system must identify those that indicate attacks or other unwanted actions against the CI. Traditional methods of detecting such information are typically time-consuming.

Problem Statement. In general, a SIEM system has "agents"—"data warehouse"—"application server" architecture deployed on the protected information infrastructure. Agents collect security events, perform their initial processing, and filter them. The collected and filtered security event information is sent to a data warehouse or repository, where it is stored in an internal format for further use and analysis by the application server. The application server implements the core IS functions. It analyzes the information stored in the repository and transforms it to develop alerts or management decisions to protect information. Thus, a SIEM system can be divided into three architectural layers: data collection, data management, and data analysis.

At the first level, *data is collected* from various types of sources. These include file servers, database servers, Windows servers, firewalls, workstations, IPS (Intrusion Prevention Systems), antivirus programs, and so on.

The second level *manages security event* data stored in the repository. The data contained in the repository is retrieved by queries from data analysis models.

The results of information processing in a SIEM system obtained at the third level are reports in a defined and arbitrary form, online correlation of event data, and alerts generated online and/or sent by e-mail.

How the SIEM System Works

A SIEM system combines the functions of two different classes of IS monitoring and management systems:

- SIM (Security Information Management) and SEM (Security Event Management). The functionality of a SIM system includes collecting, storing, and analyzing logs, as well as generating the necessary reports.
- SEM systems provide real-time monitoring [3] of security events, as well as detection and response to security incidents.

The implementation of the above functions in a SIEM system forms the basis for the implementation of a number of different functional mechanisms. In SIEM systems, these mechanisms typically include event normalization, filtering, classification, aggregation, correlation, and prioritization, as well as report and alert generation. The latest generation of SIEM systems should incorporate additional functionalities such as event and incident analysis, consequence analysis, decision-making capabilities, and visualization tools [4, 5]. Let us delve deeper into these features:

- Normalization is the process of converting the formats of log records collected from different sources into a single internal format that is then used for storage and further processing.
- Security event filtering is the removal of redundant events from the streams entering the system.
- Classification allows security event attributes to be assigned to a particular class.

- Aggregation combines events that are similar in some way.
- Correlation reveals relationships between heterogeneous events, enabling the detection of CI attacks and violations of security criteria and policies.
- The prioritization feature allows the SIEM system to determine the level of importance and criticality of security events based on predefined rules within the system.
- The event, incident, and consequence analysis feature involves modeling events, attacks, and their consequences, analyzing system vulnerabilities and security, identifying intrusion parameters, evaluating risks, and predicting future events and incidents.
- Generating reports and alerts means generating, transmitting, displaying, and/or printing the results of operations.
- Decision-making determines the development of actions to reconfigure security measures to prevent attacks or restore infrastructure security.

Visualization includes the presentation of data in graphical form that characterizes the results of the analysis of security events and the state of the CI and its elements. The interconnection of the mechanisms of the new generation SIEM system is clearly demonstrated by the functional model, which identifies five main functional subsystems: data collection; processing; storage; analysis; and presentation. The first two are online, while the rest are close to it. Here is a brief description of these subsystems:

1. *Data Collection Subsystem.* There are two main methods used to obtain information from sources: Push and Pull. The main feature of the push method is that the source itself sends data from its logs to the SIEM system. The pull method is where the system itself performs the process of retrieving data from the logs. Data is collected from various types of sources.
2. *Processing subsystem.* Information processing includes normalization, filtering, correlation, aggregation, and classification.
3. *Storage subsystem.* Filtered data in normalized form is placed in a repository for storage. The repository can be based on a relational DBMS (Database management system), the most common solution, an XML-oriented DBMS, and/or a triplet repository. A triplet repository is a specially created database optimized for storing and retrieving triplets, i.e., statements of the subject-predicate-object type.
4. *Analysis subsystem.* Data analysis includes the following functions: data correlation, classification, aggregation, prioritization and analysis of events, incidents, and their consequences, as well as decision support. Data analysis may involve both qualitative and quantitative assessments. Quantitative assessment is more accurate, but takes significantly more time, which is not always acceptable. Often, a quick qualitative analysis is sufficient, with the task of categorizing risk factors into groups. The extent of the qualitative analysis may vary from one assessment method to another, but it all boils down to identifying the most serious threats.
5. *Presentation subsystem.* The view includes several functions: visualization, report generation and alert generation.

Based on these statements, there is an important scientific need to analyze existing SIEM systems and develop a universal system for correlating events and managing cybersecurity incidents at CI facilities.

2 Literature Review

In order to obtain certification, all Security Information and Event Management (SIEM) systems must adhere to a set of internationally recognized security standards. These standards include ISO/IEC 27,000, PCI-DSS, HIPAA, NIST 800–171, DoD, RMF, and GDPR. To address the problems related to the security and event recording of SIEM systems, [6, 7] considered the main features of the functioning of existing SIEM systems and conducted a comparative analysis. Let us consider some of them in more detail.

2.1 IBM QRadar Security Intelligence Platform

Reference [8] is a set of interconnected technologies specifically designed for the purpose of gathering events, monitoring, analyzing security, and investigating incidents. The systems encompassed in this list are Log Manager, SIEM, Flow Processor, Vulnerability Manager, Risk Manager, Network Insights, Watson Advisor for Cyber Security, Packet Capture, and Incidents Forensics. QRadar has the capability to gather and analyze data on security events from security audit logs. It can also analyze network statistics like NetFlow, independently analyze network traffic and transmitted information, create network topology, simulate changes in network device configuration files, identify vulnerabilities and insecure systems, capture traffic in its entirety, and reconstruct the sequence of communication between network nodes. The benefits of IBM QRadar include:

- QRadar Security Intelligence Platform offers a unified solution for creating a comprehensive SOC that includes collecting, analyzing, and responding to security events, detecting anomalous network activity, scanning for vulnerabilities, and identifying unsafe configurations. It integrates with IBM Watson AI and network forensics for enhanced functionality and incident response in IBM Resilient.
- The QRadar Platform's flexible architecture enables customers to customize the roles and functions of the platform modules to suit their needs without being constrained by a predetermined framework.
- QRadar Platform offers numerous free software, content, and integration modules, providing customers a wide range of options to enhance their security operations.

2.2 LogRhythm

Reference [9] is an intelligent security solution platform that utilizes artificial intelligence for log and traffic analysis in Windows and Linux operating systems. Some advantages of the system include:

- Includes an extensible data warehouse.
- Suitable for systems that lack structured data, centralization, or automation.
- It is particularly suitable for small and medium-sized organizations.
- The platform enables filtering unnecessary information or logs and focusing on network-level analysis.
- LogRhythm is highly interoperable with a diverse array of logs and devices, and seamlessly interacts with Varonis to bolster threat and incident response capabilities.

2.3 Splunk

Is a tool that employs artificial intelligence and machine learning to provide practical, efficient, and anticipatory insights. It can be used by organizations of any size, whether for on-premises or SaaS deployment. The tool has several advantages, including:

- Rapid detection of threat.
- Identifies and assesses risk.
- Manages alerts.
- Organizes events.
- Responds quickly and effectively.
- Works with data in the local environment as well as in the cloud infrastructure.

2.4 McAfee Enterprise Security Manager (ESM)

Reference [10] can be deployed as a physical or virtual application, and it comprises three main components: ESM, Event Receiver, and Enterprise Log Manager. These components can be deployed together or separately, depending on the needs of distributed or large environments. Some of the advantages of McAfee ESM are:

- ESM provides robust coverage for Industrial Control Systems (ICS) and Supervisory Control and Data Acquisition (SCADA) devices.
- McAfee ESM benefits from the strong coverage of Industrial Control System and Supervisory Control and Data Acquisition Devices.
- McAfee Data Exchange Layer (DXL) enables integration with third-party technologies without requiring APIs, thus allowing ESM to function as an SIEM platform.

- Flexible and customizable dashboards, reports, and alerts that provide real-time insights and enable proactive threat response.
- McAfee Global Threat Intelligence extends the capabilities of the Enterprise Security Manager SIEM by adding a source of continuously updated threat intelligence that helps quickly identify events containing sessions from suspicious or malicious IP addresses.

2.5 AlientVault USM

Is a security management platform that streamlines threat detection, incident response, and compliance management across cloud and on-premises environments. It offers several key features, including [11]:

- Third-party security applications can have their security data extracted and analyzed by AlienVault USM, which can also manage their actions based on the threat data it collects. The platform offers a rich graphical dashboard to visualize the external data and supports advanced security features by adding new AlienApps modules.
- With AlienVault USM, users can centrally collect and analyze security data from various third-party applications and devices and view the results in a user-friendly dashboard.
- The platform allows for managing the actions of third-party security solutions based on the analyzed threat data and provides advanced security features through the integration of AlienApps modules.

2.6 FortiSIEM

Is a security, performance, and compliance management tool that can handle all infrastructure components, including clouds and the Internet of Things (IoT). It is designed to simplify threat detection and improve the efficiency of the security system while sharing information about detected vulnerabilities [12–14]. The main benefits of FortiSIEM are:

- Scalable and flexible log collection capabilities.
- Incident reporting and management functions.
- Customizable and functional dashboards for users.
- Integration with external threat intelligence.
- Scalable analytics to handle large amounts of data.
- Ability to establish baselines and identify statistical anomalies in endpoint/server/user behavior.
- Seamless integration with external technologies.

2.7 Ixia ThreatARMOR

Provides the following capabilities:

- Ensures maximum bandwidth utilization by allowing all legitimate traffic and blocking traffic only from known malicious sites and untrusted countries.
- Reduces false positives by providing visual confirmation of all blocked sites' malicious actions.
- Improves efficiency by reducing the number of security alerts generated.
- Updates threat data every 5 min through a cloud-based update subscription (ATI).
- Quickly detects compromised internal systems.
- Blocks connections to known malicious IP addresses.
- Offers dual power redundancy and built-in bypass capability for maximum reliability.
- Provides an easy 30-min setup with centralized cloud-based management, requiring no further customization.
- Increases the return on investment and productivity of network security infrastructure.

2.8 MozDef Mozilla

SIEM system [10, 15] is a platform that automates security incident handling processes. It has been designed with a microservice architecture to achieve maximum performance, scalability, and fault tolerance, with each service running in a Docker container. The system has the following advantages:

- No agents are required as it works with standard JSON protocols.
- The system is easily scalable using the microservice architecture.
- It can support data sources from cloud services, such as AWS CLOUDTRAIL and GUARDDUTY.

2.9 Wazuh

The main advantages of the system:

- OSSEC is a widely used SIEM tool [16] that this system is based on.
- This system offers different installation choices, including DOCKER, PUPPET, CHEF, and ANSIBLE.
- Enables the surveillance of cloud services, such as AWS and AZURE.
- The system has a thorough set of guidelines for identifying different sorts of attacks and enables correlation in accordance with PCI DSS V3.1 and CIS standards.
- The system smoothly integrates with the SPLUNK log storage and analysis system, allowing for event visualization and API support [16].

2.10 Prelude OSS

Is a flexible modular SIEM system [16] that has been in development and use since 1998. It supports multiple log formats and can integrate with third-party tools such as OSSEC, Snort, and the Suricata network detection system. Some advantages of the system, as stated in [16, 17], include:

- Support for a variety of log formats.
- Data normalization to the IMDEF format, simplifying data transfer to other security systems.

2.11 Sagan

It has the following advantages:

- It is fully compatible with the SNORT database, rules, and user interface.
- Its multi-threaded architecture enables high performance. These advantages have been reported in [16].

2.12 SolarWinds

Offers a wide range of capabilities for log management, reporting, and real-time incident response [9, 18]. The system's key features include:

- Quick identification of suspicious actions and potential threats.
- Continuous monitoring of the security landscape.
- Accurate timing of events.
- Compliance with various standards such as DSS, HIPAA, SOX, PCI, STIG, and DISA.
- The SolarWinds solution caters to both small and large businesses, and it can be deployed on-premises or in the cloud, running on both Windows/Linux platforms.

2.13 ManateEngine

Is a Security Information and Event Management (SIEM) solution that specializes in analyzing diverse logs and extracting a wide range of performance and security data from them. The targeted areas encompass critical hosts and applications, such as web servers, DHCP servers, databases, print servers, email services, etc. Furthermore, the ManageEngine analyzer, compatible with both Windows and Linux operating systems, proves valuable in ensuring systems adhere to data protection standards such as PCI, HIPPA, DSS, ISO 27001, and others [14, 19].

2.14 EventTracker

Key features of this SIEM platform:

- Real-time alerting and incident response. The system uses rule-based alerts to quickly identify and respond to potential security threats, providing dashboard updates and remediation recommendations.
- Search and forensic analysis. Journals are indexed in Elastic Search using an extensible general indexing model, making it easy to search and analyze data for forensic purposes.
- Reporting. EventTracker includes over 1500 pre-built security and compliance reports, with full support for a range of industry standards and regulations such as PCI-DSS, HIPAA, ISO 27001, NIST 800–171, DoD, RMF, GDPR, and more.
- Behavioral analysis and correlation. The platform leverages real-time processing and correlation to detect and explain changes in system and user behavior, providing a complete picture of what is new and unusual.
- Threat analysis. EventTracker integrates with threat intelligence feeds from ecosystem partners and open-source vendors to provide fast and accurate threat detection for networks [20].

2.15 Trustwave SIEM Enterprise

Benefits from Trustwave:

- Other security product users who rely on Trustwave will have enhanced bi-directional integration with Trustwave's technologies, which offer automated response capabilities like suspending user accounts and quarantining compromised endpoints.
- Trustwave's portfolio of technologies, which support automated response capabilities like quarantining compromised endpoints or suspending user accounts, will provide benefits to users of other security products who have integrated with Trustwave.
- Trustwave's SIEM Enterprise has a straightforward architecture that simplifies the deployment and expansion process for customers, reducing their workload [18].

2.16 BlackStratus SIEM Storm

The BlackStratus SIEM Storm appliance provides flexible threat visualization and mitigation tools for distributed networks. SIEM Storm integrates with existing network and security devices to provide the following advanced capabilities [18, 21–23]:

- Advanced Architecture. BlackStratus SIEM Storm provides complete failover and tiered redundancy to meet complex regulatory, business continuity, and risk management requirements.
- A Real-Time Attack Visualization. Detect zero-day attacks using sophisticated metrics based on rules, vulnerabilities, statistical and historical correlations.
- Vulnerability correlation involves integrating data from intrusion detection systems that comply with CVE standards. This integration helps to eliminate false positives and allows teams to concentrate on actual threats.
- Visibility. Acquire unparalleled visibility into distributed networks, enabling the correlation of activity across individual network environments and the identification of hidden threats, suspicious trends, and other potentially harmful behavior.
- Reporting. Application provides the ability to report easily and make it in compliance with the following international security standards, for instance SOX, ISO, PCI, HIPAA, and other.

Table 1, as referenced in sources [6, 7], organizes and provides a comprehensive examination of SIEM systems based on 18 specific criteria (as suggested by the authors).

1. Evaluation and enforcement measures for ensuring adherence to regulations and standards.

Table 1 Comparative analysis of SIEM systems

Title no	Criteria																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	–
2	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	–
3	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	–
4	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	–
5	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	–
6	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	–
7	+	+	+	+	+	+	+	+	+	+	+	+	–	–	+	+	+	–
8	+	+	–	+	–	+	+	+	+	+	–	+	+	+	+	+	+	+
9	+	+	–	+	–	+	+	+	+	+	+	+	+	+	+	+	+	+
10	+	+	–	+	+	+	+	+	+	+	+	+	–	–	–	+	+	+
11	–	–	–	–	–	+	+	+	+	+	–	+	–	–	–	+	–	+
12	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	–
13	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	–
14	+	+	–	+	–	+	+	+	+	+	+	+	+	+	–	+	+	–
15	+	+	–	+	+	+	+	–	+	+	+	+	+	+	–	+	+	–
16	+	+	–	+	–	+	+	+	+	+	+	+	–	–	–	+	+	–

2. System completion is indicated by a "+" for full completeness and a "−" for log processing only.
3. Evaluation of the security of monitored system resources, including CBR.
4. Verification of compliance with the information security management system.
5. Information Systems risk management.
6. Acquiring and retaining events that enter the system.
7. Processing and evaluating recorded occurrences.
8. Identify and ascertain instances of assaults and breaches of security policies.
9. Determine and evaluate security issues.
10. Conduct inquiries.
11. Search for vulnerabilities.
12. Create reports.
13. Assistance for operating in cloud environments.
14. Assistance for collaborating with large-scale data platforms.
15. Capacity to seamlessly incorporate with next systems.
16. Enhanced search functionalities.
17. Intuitive interface.
18. Potential for unrestricted utilization.

Table 1 provides an overview of modern SIEM systems and other IS systems that perform their functions. The main focus is on their functionality, the basic principle of operation, and a comparative analysis of their capabilities and differences, as well as the advantages and disadvantages of their use. International specifications and standards were also analyzed to ensure compliance. Based on the investigation, the most efficient systems are IBM QRadar, LogRhythm, Splunk [24], McAfee (ESM), AlienVault USM, FortiSIEM, SolarWinds, and Mana-teEngine (highlighted in gray in Table 1). These systems match the majority of the requirements but vary in terms of cost. Given the above, it is reasonable to develop a universal SIEM system that incorporates all the above-mentioned features and benefits. The purpose of this paper is to develop, implement, and experimentally investigate a system for correlating events and managing cybersecurity incidents in critical infrastructure facilities. The system must meet certain criteria and provide both effective correlation of cybersecurity events and management of incidents that occur in and impact CI.

3 Theoretical Framework for Creating a System to Establish Connections Between Events and Effectively Handle Cybersecurity Incidents

The study found that it recommended the use of open-source applications, given the cost and the ability to add functionality to meet the needs of a particular CI facility. From the security point of view, the best option is to develop an in-house cybersecurity event correlation and incident management system (hereinafter—"ECIMS") at CI

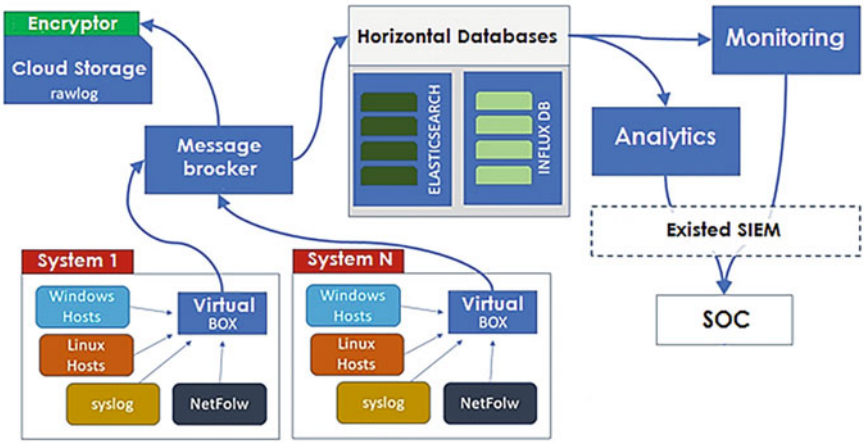


Fig. 1 The architecture of developed by the ECIMS

facilities that has comprehensive IS functionality, is flexible and scalable, and is protected from possible vulnerabilities and backdoors.

The paper proposes a universal solution based on the use of a cloud-based SIEM system for the CI industry [7] and develops the concept of the architecture of ECIMS. Figure 1 shows the architecture of the proposed system, which is focused on use in various sectors of CI with the support of cloud technologies. The proposed system can be integrated into real infrastructures with different SIEM systems or other incident management tools in operation. The main entities of the ECIMS system are horizontal databases.

- Block for analytics.
- Surveillance unit.
- Cloud storage.
- An encryptor is a tool used to encrypt data.
- A message broker.
- Sources (System 1 to System N).

The ECIMS developed models for the operation of a hybrid security data warehouse, which differs from analogues in that it combines two different types of databases—in particular, for fast processing of logs, a scalable open-source full-text search engine Elasticsearch (using the Lucene library written in Java, JSON document format), and an open document-oriented database MongoDB (using JSON-like documents and a database schema written in C++). This approach enables the indexing service to retrieve data from external data warehouses, ensuring accurate indexing and display of data during searches. It is designed to scale and cluster effectively as the volume of data increases. Additionally, it supports various types of queries, including simple, complex, and structured queries, as well as different types of data. This approach allows for aggregation, analysis, pattern collection,

streamlined search, and high search speed. Furthermore, a Security Information and Event Management (SIEM) system [25, 26] built upon the suggested models has the capability to operate with multiple replicas, meaning it can store two or more copies of data on separate nodes. It can also expand horizontally by segmenting database objects, and can function as a file storage system with load balancing and data replication, known as the Grid File System function.

It develops models, methods, and algorithms for distributed data bus (DDB) operation, which differ from analogues in that they use their own agents for collecting information (events), which are installed in the controlled systems, and existing standard event collection mechanisms (syslog, snmp, etc.); integration scenarios with the possibility of modification with minimal intervention of developers are used; DDB for network control can be used as a collector of NetFlow statistics obtained from network devices, as well as for analyzing network traffic as a result of using the network. By employing this approach, fast processing of large information flows is ensured, with minimal delays in data processing and report generation. Additionally, this approach offers high fault tolerance, flexibility, and storage expandability without downtime by adding nodes.

From a security point of view, an important role in this system is played by the Encryptor, which is a single unit with the Cloud Storage, thus ensuring the confidentiality of the raw records after collection by syslog, NetFlow, etc. agents. In addition, the Virtual BOX sends the collected data in encrypted form through the Message Broker to the Horizontal Databases. In case of failure of communication with the Message Broker, the data is temporarily stored in the cloud storage, as already mentioned.

Moreover, the ECIMS system has been incorporated into software, and the subsequent phase involves conducting an experimental investigation of the software solution as an information system tool. This investigation aims to meet specific criteria and ensure the efficient correlation of cybersecurity events and incident management within the critical infrastructure, which in turn affects crucial resources.

4 Investigation of Developed Method via Experimental Study

The system that has been created automates the process of prioritizing security threats [27] and violations of IS policies. This is done by analyzing and correlating IS events. The ECIMS system scrutinizes each instance of user login and logout, as well as all activities related to accessing resources (including authentication information), executing database queries, and conducting transactions. The system offers the capability to gather, retain, and examine events from any origin at any given moment. Conduct a thorough examination of events and identify any abnormal or

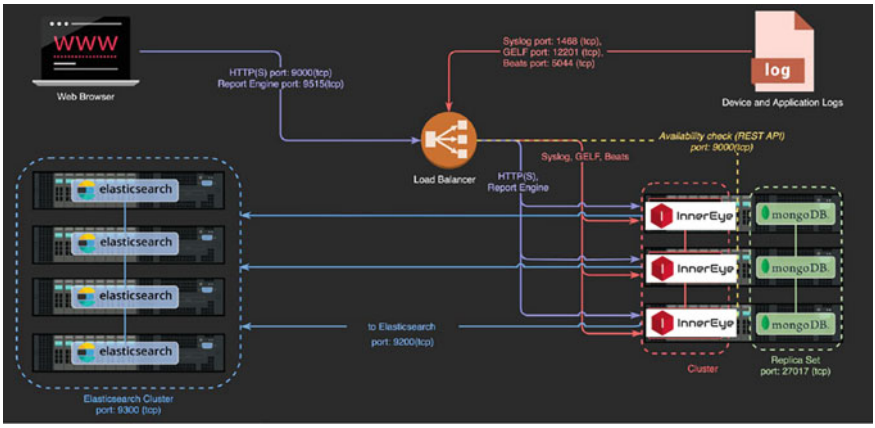


Fig. 2 Example of up to 300 GB of events per day for a ECIMS architecture

unlawful acts. Modifiable graphical dashboards for monitoring events. An application programming interface (API) that allows seamless integration with external systems and services.

System architecture. The system has a great degree of flexibility and can be horizontally scaled. The Elasticsearch NoSQL database is utilized for storing events, whereas the MongoDB NoSQL database is employed for storing all configuration and rule information. The system can be deployed in several versions based on performance and reliability needs. Figure 2 depicts an instance of ECIMS system architecture.

Utilizing clusters in ECIMS guarantees optimal system performance and dependability, while also enabling adaptable customization to meet individual situations.

System capability. Origins of incidents

The system facilitates the use of conventional techniques for gathering event logs (refer to Fig. 3). These techniques comprise the following elements:

- Syslog can be transmitted using TCP, UDP, AMQP, or Kafka protocols.
- GELF supports various protocols like TCP, UDP, AMQP, Kafka, and HTTP.
- Amazon Web Services (AWS) provides many logging services, including AWS Logs, FlowLogs, and CloudTrail.
- Beats/Logstash.
- CEF supports various protocols including TCP, UDP, AMQP, and Kafka.
- The JSON Path is obtained from the HTTP API.
- Netflow/IPFIX is a protocol that uses UDP for communication.
- Unformatted Text (TCP, UDP, AMQP, Kafka).

It is possible to establish a separate receiver, referred to as an Input, with specific characteristics for each sort of event source. Users have the ability to access general information for each event source and can choose to view events specifically from

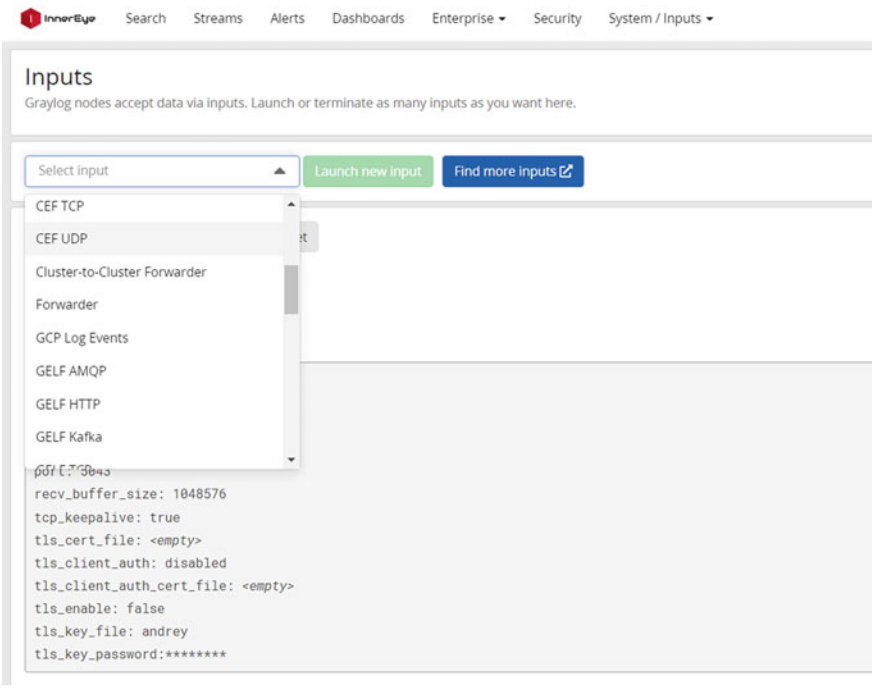


Fig. 3 Event Source Type Selection Menu

that source. Furthermore, it is possible to configure protocols that facilitate secure data transport, such as TLS, by adjusting the relevant parameters.

Storing Events in the Database. The ECIMS saves events in the Elasticsearch NoSQL database management system. Within the Elasticsearch DBMS, it is feasible to generate a limitless number of databases, also known as indexes (Fig. 4).

Event Processing and Threading

Threads provide as a means for classifying events into real-time categories as they are being handled (Fig. 5). It is feasible to generate a limitless number of threads, taking into account the server hardware's physical constraints and the limitations of the MongoDB database.

The allocation of events among threads is the foundation of the rules. The system allows users to create and change rules for distributing events among threads. Threads enable the immediate processing, reporting, and transmitting events to external systems, such as relaying information regarding database faults to another system.

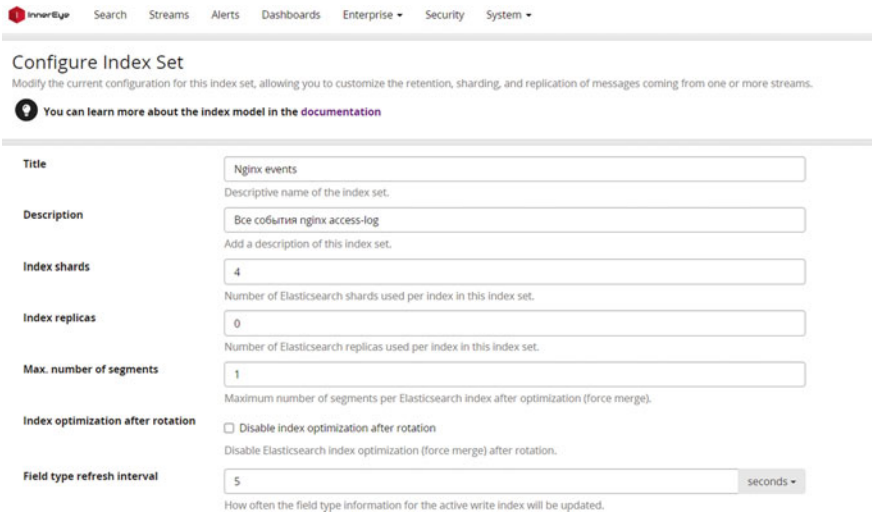


Fig. 4 Setting up database (index) parameters

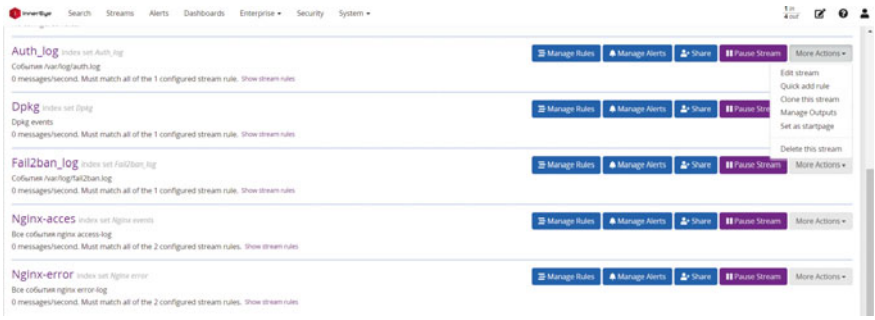


Fig. 5 Common information about flows and actions that can be taken

Event Processing. Transmission Systems and Operational Guidelines

Pipelines are a fundamental notion that integrates sequential processing stages applied to events. Pipelines consist of rules and can be linked to one or more threads, enabling fine management of event processing (Fig. 6).

Pipelines do not have control flow since their processing rules consist of conditions followed by actions. Due to this rationale, pipelines are structured with a distinct concept known as stages. Stages consist of sets of criteria and activities that must be carried out in a specific order. Concurrent execution occurs for stages with equal priority across all interconnected pipelines. The steps in the pipeline enable control flow, enabling the assessment of whether the subsequent stages should be executed. These unnamed stages are executed in accordance with their priority order, which can be any positive or negative integer. By following a prioritized sequence, specific rules

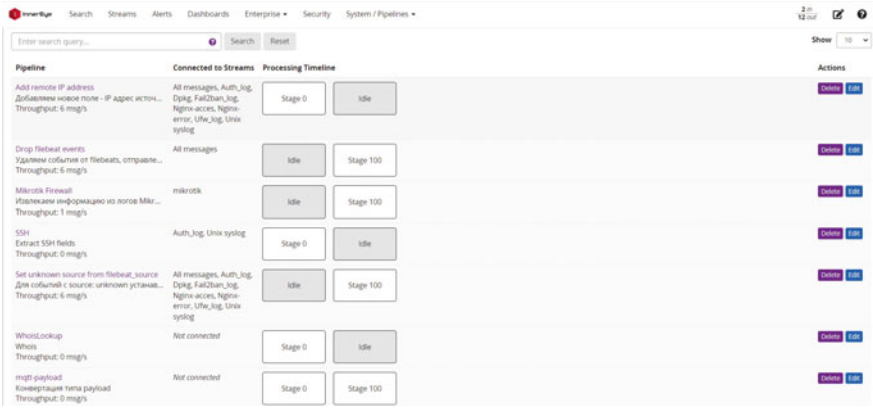


Fig. 6 General knowledge of flows and possible courses of action

can be executed before or after others in interconnected pipelines, without making any changes to those pipelines (Fig. 7).

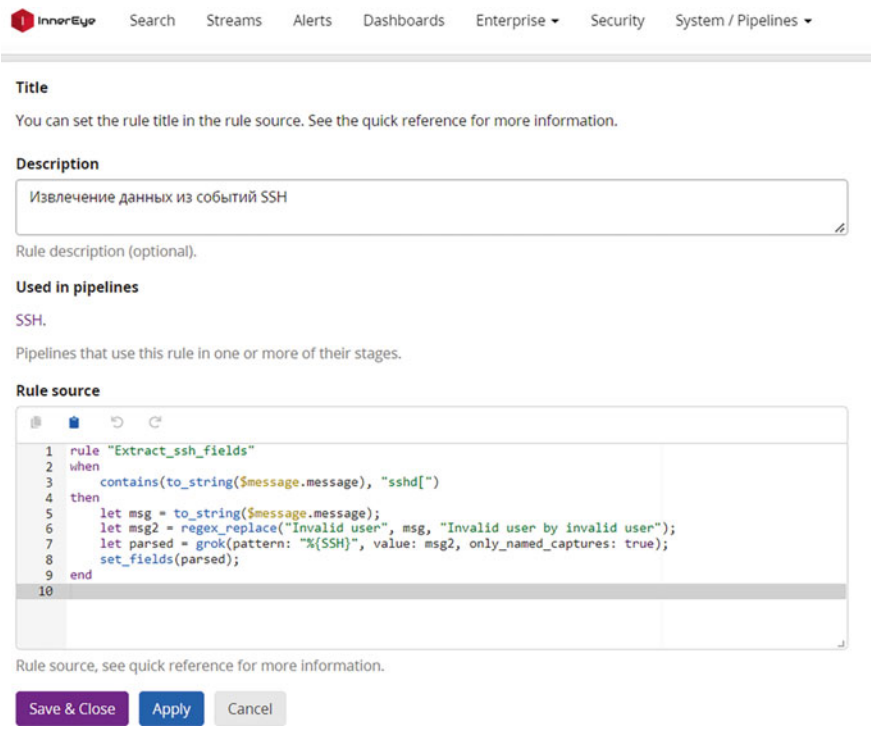


Fig. 7 Generating and modifying processing rules

Rules serve as the fundamental basis for processing pipelines. They encompass instructions on how to alter, add to, direct, and remove communications. Functions are responsible for processing messages. ECIMS incorporates numerous pre-installed routines that facilitate data conversion, manipulation of strings, extraction of data using lookup tables, parsing of JSON, and other functionalities. Rules are identified by their names and can be used by many processes. The objective is to facilitate the development of reusable standardized components that streamline the handling of data related to particular use cases.

Events and Alerts

An event is a phenomenon that links messages originating from sources (in a message stream) to a specific time period or grouping. Events serve the purpose of categorizing related fields, modifying field content, or generating new field material to be utilized in alerts and correlation rules.

The process of creating or updating an event involves multiple steps. The initial phase involves establishing the comprehensive characteristics of the event. In the second phase, utilizing a filter and aggregation, one can precisely define the criteria for identifying an event. The filter is established by means of a search. In order to narrow down the search area, users have the option to select the specific stream in which they are searching for messages. Additionally, it is feasible to specify the timeframe during which the filter will seek communications in the reverse direction. The search will be conducted within the designated time frame. The subsequent action involves generating adaptable fields (Fig. 8) that enable the population of the event index with data extracted from the source log. This obviates the necessity for the operator to conduct future searches in order to get crucial information, and also enables them to restrict the quantity of data transmitted to the notification destination. The event is logged in the All Events stream and includes the user field along with the outcome of the aggregate that triggered the event.

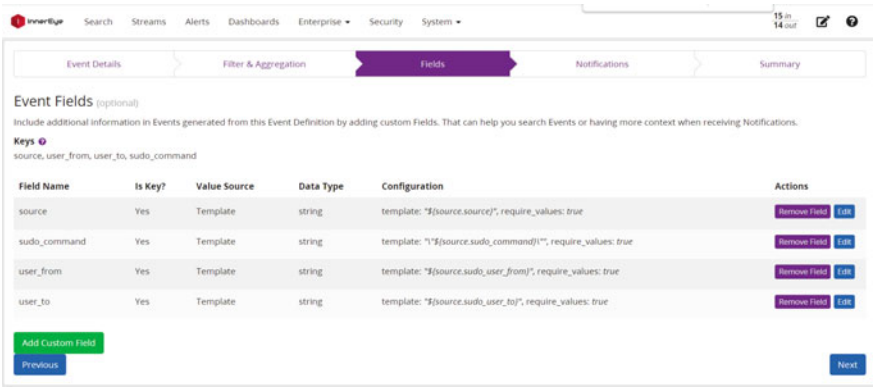


Fig. 8 Creating an event involves editing a configurable field

Subsequently, it is feasible to establish a connection to a notification event, resulting in the event status being elevated to an alert (Fig. 9). The final step involves verifying the parameters and saving the event configuration. The Alerts & Events page provides comprehensive information regarding all events and alerts.

Dashboard Panels for Displaying Information

Dashboards enable the creation of preconfigured data searches. This feature enables users to get crucial information effortlessly by only clicking once. Dashboards establish precise search criteria, such as a query or a specified time span. Figure 10 demonstrates the capability of dashboards to establish many tabs for various purposes and allows users to evaluate the outcomes in full-screen mode.

Search

The search page serves as the central component of the ECIMS. The tab (Fig. 11) allows users to search (query) and view the outcome using several widgets. Each

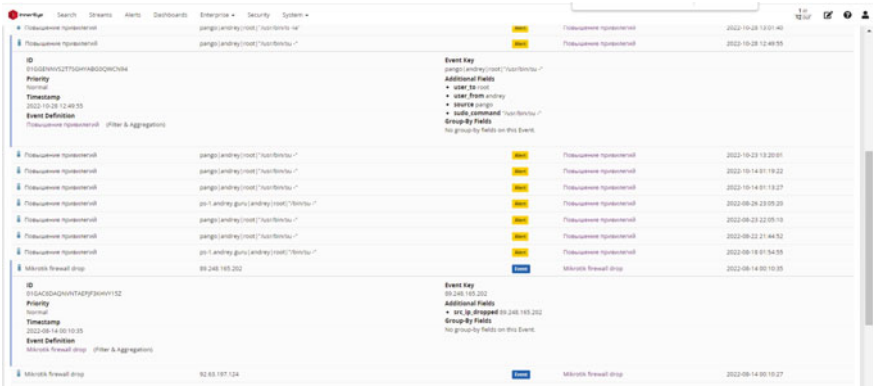


Fig. 9 Event information and alerts

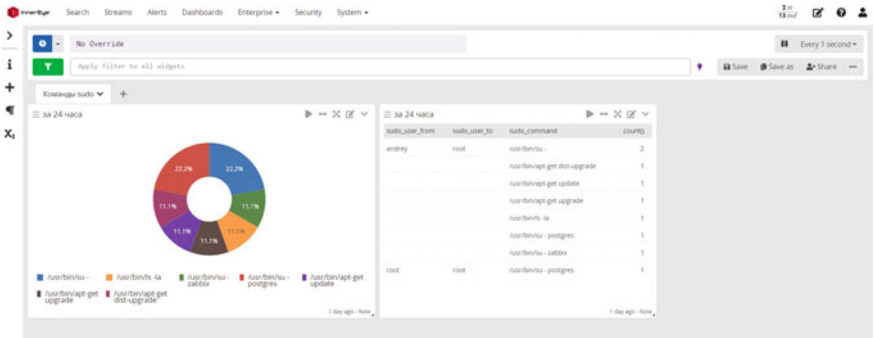


Fig. 10 Dashboard. Default presentation

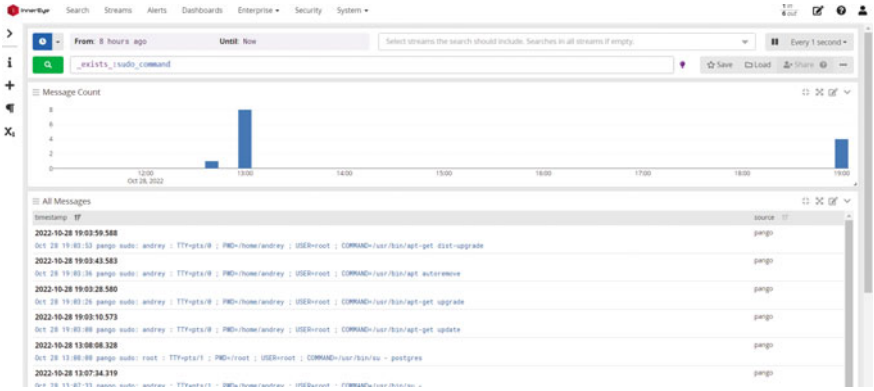


Fig. 11 Search field. Overview

search can be saved or exported to the dashboard. Saved queries provide a convenient way to reuse unique query configurations, while dashboards allow for widget-specific searches that may be shared with other users for their own workflows.

Following the completion of the experimental research of the system based on the created architectural concept, a load test was undertaken to verify the effectiveness of the solutions (modules) employed in the produced ECIMS. The test confirmed their high efficiency. Furthermore, the source code underwent a thorough vulnerability scan utilizing specialist tools, which revealed no significant flaws. The created system facilitates the efficient correlation of cybersecurity events and the management of incidents that occur in the critical infrastructure (CI) and affect the important resources.

5 Conclusions

The study provides an examination of current SIEM systems, outlining their functionality and fundamental operational concepts, and evaluating their adherence to international specifications and standards. The investigation reveals that the most efficient systems are IBM QRadar, LogRhythm, Splunk, McAfee (ESM), AlienVault USM, FortiSIEM, SolarWinds, and ManateEngine. These solutions satisfy the highest number of criteria but vary in cost. Considering the investigation findings, a comprehensive ECIMS for CI facilities was created using open modules, incorporating all the aforementioned characteristics and advantages. Hybrid security data warehouse models have been created to enable the indexing service to retrieve data from external data warehouses. These models can adapt to increasing data volume, handle various queries and data types, facilitate aggregation, analysis, and pattern collection, streamline search processes, and deliver fast search results. Distributed storage models, techniques, and algorithms have been developed to ensure high

processing speed of large information flows, minimal latency in data processing, minimal latency in building analytical reports and queries, high fault tolerance, flexibility, and storage expandability by simply adding nodes without downtime.

The ECIMS is designed to solve several cybersecurity-related tasks, such as registering users' actions when using the organization's information resources (including critical resources) in system logs, periodically monitoring the correctness of system users' actions by analyzing the contents of system logs; controlling the integrity (ensuring the immutability) of the program execution environment and restoring it in case of a violation; protecting information from unauthorized modification; maintaining the integrity of the software tools used, as well as protecting the system.

In addition, an experimental study of the ECIMS was conducted and it was verified that the developed system meets the requirements set based on the analysis of international standards and best practices for the creation of cyber incident management systems, which relate to the purpose of the system; centralized management of system components and functionality; data visualization through appropriate interfaces; support for an open API; support for authentication and authorization; the possibility of automatic and/or manual updating; and the ability to The ECIMS can be used to manage incidents that occur in the CI and have an impact on the critical resources.

References

1. Buriachok, V., Sokolov, V., Skladannyi, P.: Security rating metrics for distributed wireless systems. In: Proceedings of Workshop of the 8th International Conference on Mathematics, Information Technologies, Education: Modern Machine Learning Technologies and Data Science (MoMLeT and DS), Vol. 2386, pp. 222–233 (2019)
2. Kipchuk, F. et al.: Investigation of availability of wireless access points based on embedded systems. In Proceedings of 2019 IEEE International Scientific-Practical Conference on Problems of Infocommunications, Science and Technology (PIC S&T) (2019)
3. Lasantha, C., Abeysekara, R., Maduranga, M.: A novel framework for real-time ip reputation validation using artificial intelligence. Int. J. Wirel. Microwave Technol. (IJWMT) **14**(2), 1–16 (2024). https://doi.org/10.5815/ijwmt.2024.02.01
4. Bogachuk, I., Sokolov, V., Buriachok, V.: Monitoring subsystem for wireless systems based on miniature spectrum analyzers. In: Proceedings of 2018 International Scientific-Practical Conference Problems of Infocommunications, Science and Technology (2018)
5. Pateria, J., Ahuja, L., Som, S., Seth, A.: Applying clustering to predict attackers trace in deceptive ecosystem by harmonizing multiple decoys interactions logs. Int. J. Inf. Technol. Comput. Sci. (IJITCS) **15**(5), 35–44 (2023). https://doi.org/10.5815/ijitcs.2023.05.04
6. Gnatyuk, S., Berdibayev, R., Fesenko, A., Kyryliuk, O., Bessalov, A.: Modern SIEM analysis and critical requirements definition in the context of information warfare. CEUR Workshop Proc. **3188**, 149–166 (2021)
7. Desai, P.: Enhancing cybersecurity through bayesian node profiling and attack classification. Int. J. Wirel. Microwave Technol. (IJWMT) **14**(1), 43–51 (2024). https://doi.org/10.5815/ijwmt.2024.01.04
8. IBM: Ariel Query Language Guide, IBM QRadar 7.3.3 (2013). Retrieved from https://www.ibm.com/docs/en/SS42VS_7.3.3/com.ibm.qradar.doc/b_qradar_aql.pdf
9. Vielberth, M., Pernul, G.: A security information and event management pattern. In: 12th Latin American Conference on Pattern Languages of Programs, SugarLoafPLoP 2018, pp. 27 (2018)

10. Karlzén, H.: An Analysis of Security Information and Event Management Systems. University of Gothenburg (2009). http://publications.lib.chalmers.se/records/fulltext/89572.pdf
11. Agrawal, K., Makwana, H.: A study on critical capabilities for security information and event management. Int. J. Sci. Res. (IJSR) **4**(7), 1893–1896 (2015)
12. Avkurova, Z., Gnatyuk, S., Abduraimova, B., Fedushko, S., Syerov, Yu., Trach, O.: Models for early web-attacks detection and intruders identification based on fuzzy logic. Procedia Comput. Sci. **198**, pp. 694–699 (2022).https://doi.org/10.1016/j.procs.2021.12.308
13. Gnatyuk, S., Berdibayev, R., Avkurova, Z., Verkhovets, O., Bauyrzhan, M.: Studies on cloud-based cyber incidents detection and identification in critical infrastructure. CEUR Workshop Proc. **2923**, 68–80 (2021)
14. Lee, J., Kim, Y.S., Kim, J.H., Kim, I.K.: Toward the SIEM architecture for cloud-based security services. 2017 IEEE Conference on Communications and Network Security (CNS), pp. 398–399 (2017). https://doi.org/10.1109/CNS.2017.8228696
15. Miller, D., Harris, S., Harper, A., VanDyke, S., Blask, C.: Security Information and Event Management (SIEM) Implementation. McGraw-Hill Osborne Media (2010)
16. SIEM Analytics. Retrieved from http://www.siem.su/compare_SIEM_systems.php
17. Lee, J., Kim, Y., Kim, J., Kim, I.: Toward the SIEM architecture for cloud-based security services. In: 2017 IEEE Conference on Communications and Network Security (CNS). Las Vegas, NV, pp. 398–399 (2017). https://doi.org/10.1109/CNS.2017.8228696
18. Bachane, Y., Adsi, Y., Adsi, H.: Real time monitoring of security events for forensic purposes in Cloud environments using SIEM. In: 2016 Third International Conference on Systems of Collaboration (SysCo), pp. 1–3 (2016). https://doi.org/10.1109/SYSCO.2016.7831327
19. Al Sabbagh, B., Kowalski, S.: A framework and prototype for a socio-technical security information and event management system (ST-SIEM). In: 2016 European Intelligence and Security Informatics Conference (EISIC), pp. 192–195 (2016). https://doi.org/10.1109/EISIC.2016.049
20. Serckumecka, A., Medeiros, I., Bessani, A.: Low-cost serverless SIEM in the cloud. In: 2019 38th Symposium on Reliable Distributed Systems (SRDS), pp. 381–3811 (2019). https://doi.org/10.1109/SRDS47363.2019.00057
21. Gnatyuk, S., Sydorenko, V., Yudin, O., Zhyharevych, O., Polozhentsev, A.: Method for calculating the criticality level of sectoral information and telecommunication systems. CEUR Workshop Proc. **3347**, 234–245 (2022)
22. Fkih, F., Al-Turaif, G.: Threat modelling and detection using semantic network for improving social media safety. Int. J. Comput. Netw. Inf. Secur. (IJCNIS) **15**(1), 39–53 (2023). https://doi.org/10.5815/ijcnis.2023.01.04
23. Mahmoud, R.V., Kidmose, E., Turkmen, A., Pilawka, O., Pedersen, J.M.: DefAtt—architecture of virtual cyber labs for research and education. In: 2021 International Conference on Cyber Situational Awareness Data Analytics and Assessment (CyberSA), p. 1–7 (2021)
24. Hristov, M., Nenova, M., Iliev, G., Avresky, D.: Integration of Splunk enterprise SIEM for DDoS attack detection in IoT. International Symposium on Network Computing and Applications (NCA), pp. 1–5. Boston, USA (2021). https://doi.org/10.1109/NCA53618.2021.9685977.
25. Laue, T., Kleiner, C., Detken, K. -O., Klecker, T.: A SIEM architecture for multidimensional anomaly detection. In: 2021 11th IEEE International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications (IDAACS), pp. 136–142. Cracow, Poland (2021). https://doi.org/10.1109/IDAACS53288.2021.9660903
26. Orsós, M., Kecskés, M., Kail, E., Bánáti, A.: Log collection and SIEM for 5G SOC. In 2022 IEEE 20th Jubilee World Symposium on Applied Machine Intelligence and Informatics (SAMI), pp. 147–152 (2022). https://doi.org/10.1109/SAMI54271.2022.9780759
27. Suryantoro, T., Purnomosidi, B.D.P., Andriyani, W.: The analysis of attacks against port 80 webserver with SIEM Wazuh using detection and OSCAR methods. In: 2022 5th International Seminar on Research of Information Technology and Intelligent Systems (ISRITI), pp. 1–6. Yogyakarta, Indonesia (2022). https://doi.org/10.1109/ISRITI56927.2022.10052950

Waste Management by Using Smart Technology Application

Igor Šarlina and Jaroslava Kniežová

Abstract The significant technological advances of the last two decades have unfortunately also brought with them a new trend—the acquisition of a new product and the discarding of the old one without further application. The level of recycling of e-waste is very low, so that waste rich in secondary raw materials ends up in landfills or incinerators. It can thus be concluded that all the above-mentioned facts have a negative impact on the amount of waste generation, which is increasing, on the possibility of sorting waste and on the level of recycling itself. However, this situation has a positive impact on the profitability of investment in smart technologies, because it is precisely the massive amount of diversified waste that needs to be efficiently exported, sorted, and processed that creates a great need for technical and economic staff, a very large fleet of vehicles, planning and management and, with all this, a difficult monitoring of income and expenditure.

Keywords Technological advances · E-waste recycling · Waste generation · Smart technologies · Innovation processes · Sustainable development

1 Introduction

1.1 Relevance

Current developments in smart city research and applications in the areas of manufacturing systems management, Industry 4.0, transportation, and enterprise management are variously defined. Approaches are proposed to integrate smart city innovations

I. Šarlina (✉) · J. Kniežová
Comenius University Bratislava, Odbojárov 10, 820 05 Bratislava, Slovak Republic
e-mail: sarlina4@uniba.sk

J. Kniežová
e-mail: jaroslava.kniezova@uniba.sk

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2024

P. Štarchoň et al. (eds.), *Data-Centric Business and Applications*, Lecture Notes on Data Engineering and Communications Technologies 213,
https://doi.org/10.1007/978-3-031-62213-7_13

into manufacturing systems with a view to competitiveness in the global environment, while the same innovation approach is then applied to business management. Pointing out the benefits achieved by the introduction of innovative techniques and these positive consequences could be equally applicable from the municipality to the private sphere, while the technology would remain the same only different modules would be used in each platform [1].

Knowledge about the intensity and types of innovation processes in the business sphere, as well as the representation of actors involved in the creation of innovations and the effects of innovation processes are differentiated. In their research, the findings showed that large enterprises were significantly more active than small and medium-sized enterprises in the process of innovation implementation, and foreign affiliates were more active than domestic enterprises in the process of innovation implementation [2]. In addition to the typical competitive advantages of innovation processes, there were also proven advantages in ecology, occupational safety and reduction of labor demand.

The impact of future technologies for enterprise ecosystem innovation under the broad platform of CTIF Global Capsule (CGC) covers various future technologies and their actuators, smart cities, telemedicine, satellites, unmanned aerial vehicles, cooperative wireless sensor network, remotely piloted aircraft [3]. The application and effectiveness of systems, net neutrality and the concomitant virtual business model demonstrates how dynamic the technological environment is. Given the rapidly improving level of technology bases, the compatibility between e-commerce and different systems can also be assessed [4].

Over time, the focus on processes and procedures for information/data processing and management is increasing. The global market is becoming increasingly complex due to globalization and computerization. With the increasing availability of data and information, the trading of information is becoming crucial, information is becoming more "expensive" day by day and as a result it has a definite impact on the society. There is a growing need for a common understanding of how to create, access, use and manage business information. There are various determinants of data and information processing, including generation, representation, structuring, organization, storage, retrieval, navigation, human factors in information systems, and use of information. The challenges and opportunities of business information must also be considered and presents different perspectives on business information management [5].

Multiple approaches, views and concepts for new and emerging solutions and technologies that could be successfully applied to the configuration, optimization and management of supply networks in the highly volatile environment of today's global economy. The technical, organizational, financial and social aspects of implementing a new Smart solution are different in each company. Dynamic and changing market conditions require companies to act in networks in order to maintain their competitive position [6]. Accordingly, they need to adapt their activities to other market players, which requires a Smart attitude: today's supply networks need to be sustainable, modern, adaptive, robust and innovative technology-oriented. This includes, for example, making decisions about the extent to which a business model should be

green or lean. These decisions in turn affect logistics, IT, environmental issues and collaboration between suppliers, customers, competitors and complementors [7].

The relationship between sustainability technologies and information communication, which are rapidly changing the way we live, learn and do business. Modern and future technologies can help to mitigate the global energy crisis rather than eliminate it. By combining concepts and trends such as smart homes, Big Data and the Internet of Things with their applications and with sustainability, it is quite clear that emerging and ubiquitous technologies embedded in our everyday lives can rightly be considered as solutions that will enable humanity to build sustainable development [8].

Concise and easy to communicate goals and challenges related to quality, reliability, information technology and business operations. Applied research in the areas of software reliability, electronic maintenance, and big data analytics, emphasizes the importance of sustaining current growth in the adoption of information technology in businesses, while suggesting process innovations to ensure sustainable development in the near future [9]. Overall, it addresses various areas of electronic maintenance solutions, software architectures, software reliability repair issues, preventive maintenance, industrial big data, and reliability applications in power systems [10]. The ways in which countries are currently attempting to resolve conflicts and opportunities related to quality, reliability, IT and business operations are explored, and it is suggested that internationally coordinated research agendas are essential for effective and sustainable development, with research being most effective when it uses evidence-based decision-making frameworks that lead to clear management objectives, while being organized within adaptive governance frameworks [11]. The aim should thus be to achieve the common goal of making business operations more efficient and sustainable in relation to the development of scientific and technological progress [12].

"Open", "Intelligent" and "Network" are the three key words that are currently driving innovation in information systems, increasing their potential and ability to support decision-making processes [8, 13]. The importance of these three new concepts in the context of technological and organizational innovation (cloud, smart technologies and networking) and the role they play in the development of accounting and management information systems [14]. The main objective of the book is to explore how these innovations could affect information systems, with a focus on accounting and management information systems in improving their information capabilities and accounting methodologies, performance measurement systems, data management, information system architectures and external and internal data extraction respectively [15].

Current research indicates that problems in urban areas can be effectively addressed using Smart City technologies to transform built-up areas into more efficient, sustainable and safer places to live and do business. Smart Cities, by their complexity, are a set of systems and subsystems that encompass all aspects of people's lives in cities [16, 17]. A key ingredient for success is the creation of an ecosystem of smart infrastructures that work together to dynamically interact in the present between other urban subsystems such as transport, energy, health,

housing, work and public administration [2, 18]. Solving urban infrastructure problems with smart technologies presents a holistic view of smart and future-proof cities at a system level, using big data analytics and strategies for planning future development across cities [19]. Such activities result in coverage at various levels of different urban entities and create practical solutions to apply people's intellectual and social capital, further create effective pressure for greening and environmental sustainability, increase personalization of solutions, mobility and as a result achieve a higher quality of life [20, 21].

The practical application of smart technologies in industry, especially in the manufacturing sector—innovation and adaptation are named as key elements of applicability, which means that over time, development could lead to sustainable production using new technologies [13, 22]. The research that is continuously taking place in the field of artificial intelligence (AI), other AI-based techniques—machine learning—has successfully established itself at various stages of production processes in a wide variety of manufacturing activities with the aim of sustainable production [23]. With the introduction of Industry 4.0 knowledge, AI and machine learning, the driving force of a revolution is being created where the manufacturing enterprise is being transformed into a so-called smart factory [24].

Big Data represents a significant role in smart service systems—how data is collected, applied in smart cities, supports business decision making and what the design of smart solutions should be [25, 26]. They describe that today's world is the so-called Big Data world, where everyone uses computers, smartphones, programs and the Internet [27], therefore Big Data technologies are widely applicable, which has brought great changes in all industries as well as in people's lives [28]—every country, business and all kinds of institutions are realizing that data has become the most valuable asset [29] and its analysis is becoming the core of competitiveness.

Smart technologies are interconnected systems, both hardware and software, capable of automatically solving complex and multidisciplinary problems while supporting the decisions of experts [15, 30, 31]. Applications can be numerous and very diverse—from an intelligent management decision support system to an intelligent data or image processing system [6]. The technological developments achieved nowadays, together with the cheapening of resources, have led to each entity being able to generate huge amounts of data—the equipment to generate and store information has triggered the need to develop and improve intelligent systems that automate the analysis of information and offer tools to facilitate decision-making or offer the most appropriate solution. The main innovative aspect is to solve problems for which conventional techniques do not provide satisfactory solutions in terms of quality and time [32, 33].

Supporting of information management are the activities (set of information processes) that support information management across the organization. The role of management is to ensure that tasks are completed and thus achieve the set quarterly/annual targets—this can be achieved by controlling the management entity [34]. The managing entity uses the information system(s) to review the status of the activities performed. With the help of information support, applied by various information activities, a realistic picture of the status of the ongoing activities as well as of the

object itself is created [35]. Through the knowledge and awareness of the objectives set and subsequently achieved, the management issues the necessary commands to control the activities of the object of management so that the objective can be met as best as possible [23, 36].

1.2 Goals and Objectives

Smart technologies have a great importance in the economy—they eliminate inflexibility, enable better and more dynamic solutions, help higher efficiency in spending various resources—labor, money. This dissertation focuses on waste management using smart technologies, more specifically the application of smart technologies in local governments, that is, cities in which smart technologies are applied are called smart cities. Due to the ongoing Industry 4.0, environmental global issues, it is necessary to apply smart technologies especially in the field of waste management.

There are many scientific outputs focusing on smart technologies, the concept of smart cities, the application of artificial intelligence and on the topic of waste management. The vast majority of these scientific outputs have a focus on one of the listed topics, with a smaller number of sources covering at least two or three topics. However, the literature search and expert sources revealed that there is no qualifying work (or other expert output) that covers all the above-mentioned aspects and explains both the individual elements individually and in a coherent approach. Therefore, this dissertation provides information on waste management, the innovations that are applied and presents savings opportunities. The size of the savings, however, depends on the contract with the municipality, the degree of active use of smart technologies, while it can be concluded that there is a multiplier effect—when used in an integrated way, the savings are higher than the sum of the individual savings.

This chapter has the following structure. First, we describe the whole issue of smart technologies in waste management through an economic calculation, comparing the existing situation with the potential one, and will quantify the savings that can be generated by a spectrum-wide application in the company in question.

The results of the study will also include an econometric model that will present the current issue of the increasing costs of waste management and sorting (the steadily increasing production of waste will have to be gradually sorted and treated more and more due to legislation, rather than simply landfilling) in relation to the economic incentive for consumers and producers to think much more intensively about what waste will be generated from the use of their goods/services and to motivate both consumers and producers to generate less waste and to recycle much more (producers should think at the design stage about what will happen at the end of the life cycle and how to reduce the carbon footprint).

In order to meet the main objective, a number of sub-objectives need to be defined and implemented to incorporate the lessons learnt and to clearly highlight the benefits but also the negatives associated with the application of smart technologies in waste (increased upfront costs).

As a result, it is elaborated how and where smart technologies can be applied in waste management; we thereby address the following three research questions: *(i)* What are the possibilities and requirements for the application of smart technologies in waste management? *(ii)* What are the implications of introducing smart technologies in waste management? *(iii)* What is the cost-saving implications of adopting smart technologies? The synthesis of the findings is at the end of the chapter and presents further possible research.

2 Theoretical and Conceptual Background

2.1 Attributes of Smart Technology

The concept of Smart Technology or Intelligent Technology is understood as a generalization of the concept of intelligent systems [4]. Smart technologies include mechanical systems equipped with sensors, active elements and pre-programmed controls that allow the system (structure) to adapt to unpredictable external loading conditions. The concept of smart technologies blends knowledge of the mechanical system itself, embedded sensors and controllable devices, electronic devices with integrated software that adds intelligence to the system [17, 37].

The characteristics of smart technologies can be divided into the following:

- act autonomously,
- to perceive and react independently to changes in the environment,
- maintain consistency of action over a longer period of time,
- adapt their behaviour to new circumstances [8].

Smart technologies are composed of a number of elements that communicate with each other and are needed to provide information about the actual situation—these elements are essential to be able to talk about smart technologies, as well as the fact that they provide instant information without time delays [38].

The Internet of Things (often abbreviated as IoT)—is the central element of the whole concept of smart technology, which is made up of devices that are diverse—they can be simple sensors, but also smartphones and are connected. Such connected devices with various automated systems collect information, analyze it and perform actions that facilitate work, various support activities or improve processes both inside and around the organization [39].

Edge Computing sending all data generated by devices to a centralized data center or to the cloud causes bandwidth and latency issues. The decentralized cloud offers a more efficient alternative where data is processed and analyzed closer to the point where it was created, respectively. as data does not pass through the network to the cloud or data center for processing, latency is significantly reduced, while in 5G networks—it enables faster and more comprehensive data analysis, creating the opportunity for deeper insights, faster responses and better customer experiences,

and is therefore used by many IoT devices as it ensures that only the most relevant and important data is delivered over the communications network [29, 40].

Blockchain is a distributed database that holds all records as well as changes to them and is a mechanism for smart nodes to integrate with each other using a network to communicate—blockchain technology is made up of interconnected nodes within a network that are independent of each other, functioning as a network, where each node can be part of the blockchain based on permission granted from the blocks of the blockchain. Blockchain technology is one of the most popular technologies used to secure processes and enhance system security, there are several components of a smart city that are based on IoT and blockchain technology, such as smart water monitoring, parking, homes, public lighting, buildings and waste management [41].

2.2 Smart Technologies in Waste Management

An opportunity to increase the economic and material management of waste and at the same time increase the responsible approach of the population to waste generation and separation—is through the application of smart technologies. A waste management solution using smart technology allows to monitor the collection, evaluate the data in the present and optimize the entire waste system. It is such innovative solutions that are increasingly coming to the fore in the creation of Smart Cities. Smart Cities are one of the concepts of applying the principles of sustainable development, which uses modern technology to raise the standard of living and make public administration more efficient [31, 42].

Technologies in waste management in the collection phase are primarily oriented towards the acquisition of data on the quantity and type of waste, the transfer of this data to software processing and evaluation and technologies that allow the system, i.e. collection routes and vehicles, to be optimized on the basis of the analyses carried out. From this, four basic elements applied in smart waste management solutions have been identified:

1. Smart sensors—these are ultrasonic IoT sensors that monitor waste in containers of different sizes and types,
2. Smart waste management system—a cloud-based tool that enables configuration, monitoring and management of the waste management agenda,
3. Smart analytics—an English analytical and reporting tool that allows to analyze and monitor trends and predict developments,
4. Intelligent Route Planning—a planning and optimization tool primarily focused on collection routes [10].

Smart sensors: ultrasonic sensors use an ultrasonic beam, they are able to measure any kind of waste, they can measure up to 24 times a day or at some interval. The sensor also measures the temperature in the bin and warns if the bin is overturned [30, 43].

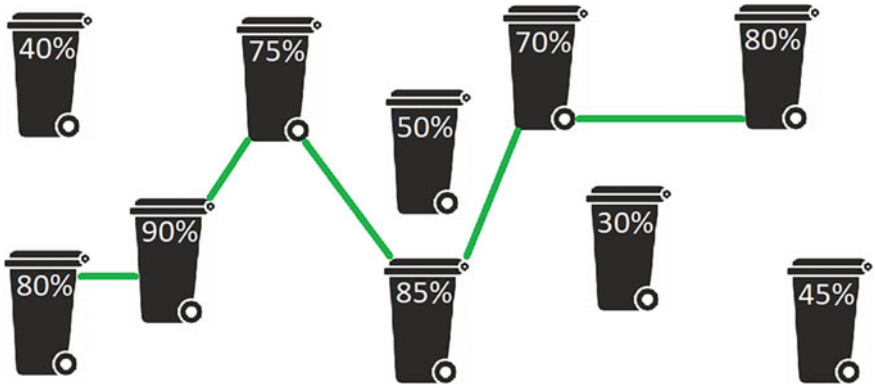


Fig. 1 More efficient collection of more filled bins according to sensor data in the same area, instead of blanket waste collection

Smart waste management system: software that works on a cloud-based platform and allows you to configure, monitor and manage your day-to-day waste management agenda. It includes an up-to-date overview of the monitored containers (fill status), and the system also allows for the planning of collection routes and semi-automatic navigation. At the same time, the system also has a mobile application version, so that in addition to the dispatcher, the current data is also available in the present time for the driver of the refuse vehicle [27].

Smart analytics: analytics and reporting tool enables users to make strategic decisions based on real data. It produces various types of statistics, reports and summaries on all monitored containers and their contents, analysis of collections and collection routes.

Smart process planning: based on real data that has been sorted and processed into a comparable form, business processes can be optimized. The route planning function automates the planning of collection routes based on detailed predefined data regarding the fleet (Fig. 1), depot and landfill or energy recovery plant [34, 44].

3 The Economic Dimension of Waste Sorting

The following subchapters will focus on the economics of waste collection and sorting. Every company has to be economically efficient and economical with its assets and human resources.

3.1 Savings Gained from the Application of Smart Technologies in Waste Management

In the city of Nitra, waste export has been optimized by creating more efficient export routes together with a reduction in frequency as needed. Furthermore, all containers have been labelled, or recessed containers have been given an internal fill sensor. Nitra Municipal Services exports waste from more than 23,500 bins and the annual waste production is approximately 49,000 tones. The company says that savings with the use of smart technologies in waste collection are 30% [9].

The application of smart sensors in the containers, which reported the current fullness in the town of Šumperk and the adjacent village of Rapotín as well as the inventory of collection containers, brought a total cost saving of 53%. Cost reductions in the sub-categories were calculated as: 58% less time required for more efficient exports (better use of collection vehicle and crew) and 61% fewer collections (less deterioration and tear on the superstructure and collection containers) [24, 45].

The automatic weighing of containers during waste collection with the application of quantitative collection together with the unambiguous identification of the payer by means of an RFID chip in the municipality of Dojč has brought savings in both main waste categories. The generation of mixed municipal waste has decreased from the original 250 tons in 2019 (without chips and weighing) to 179 tons in 2020—a 28% decrease. Another positive is that waste sorting rates—at 22% in 2018, 36% in 2019 and now over 58% in 2020—have increased by 36% over the three-year period [8, 46].

3.2 Sorted Waste Components as an Exchange Commodity

All sorted waste components are now tradable and, unlike in the past, have not only an environmental value but also a monetary value (Fig. 2). The following subchapter summarizes the sale values of the most common secondary raw materials—paper, plastics and glass.

The recovered paper had a purchase price at the beginning of the period in January 2015 of 165 Euro/tone, at the end of the period in December 2021 of 175 Euro/tone, and the median for the whole period is 170 Euro/tone [46].

Plastics that were sorted for recycling had a purchase price at the beginning of the reporting period in January 2015 of EUR 337/ton, at the end of the period in December 2021 of EUR 400/ton, and the median for the whole period is EUR 298/ton [47].

Glass to be used as an admixture had a purchase price at the beginning of the period under review in January 2015 of EUR 63/ton, at the end of the period in December 2021 of EUR 150/ton, and the median for the whole period is EUR 66/ton [48].

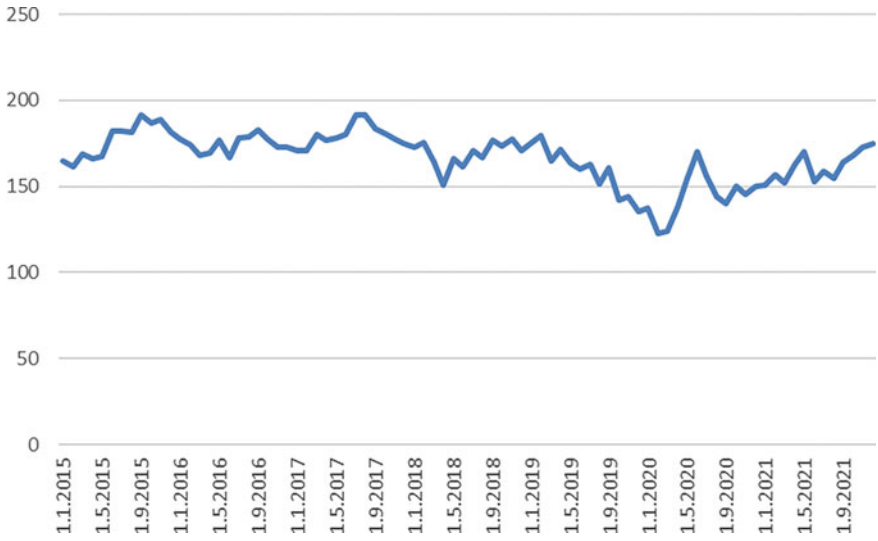


Fig. 2 Monthly development of exchange prices of sorted paper per ton

For glass, however, it is particularly noteworthy that the system of returnable beer bottles has been in operation for several decades in almost every country of the European Union, and so the recovery rate is above 95% (Figs. 3 and 4). On average it is used up to 22 times and has a lifetime of six to seven years, until the need for recycling arises [39, 49].

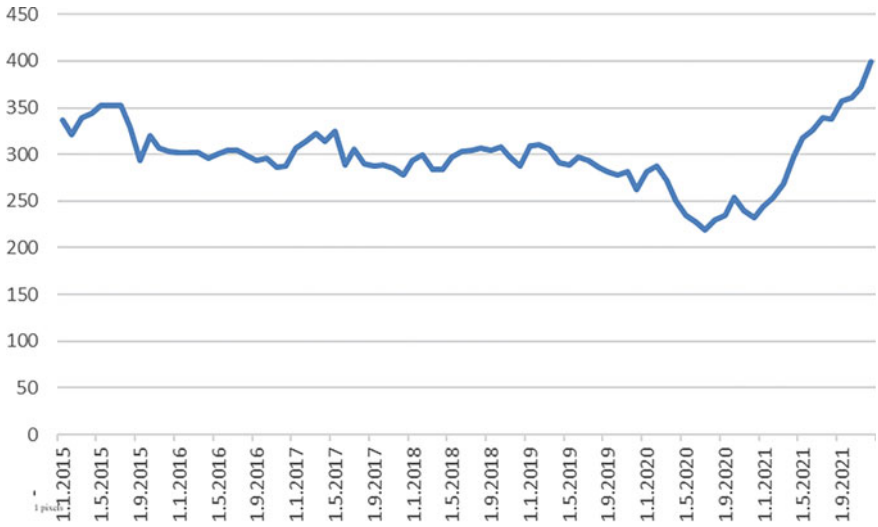


Fig. 3 Monthly development of exchange prices of sorted plastics per ton

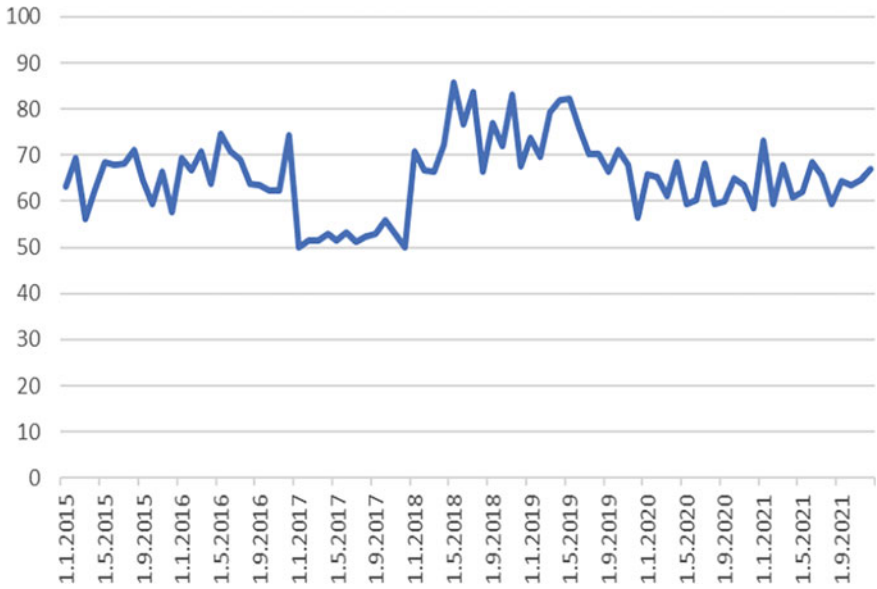


Fig. 4 Monthly development of exchange prices of sorted glass per ton

3.3 The Econometric Model

Econometrics is the use of statistical and mathematical models to build theories or test existing hypotheses in economics and to predict future trends based on historical data. Real-world data are subjected to statistical tests and the results are then compared with the theory being tested. Depending on whether existing theories are tested or existing data are used to generate a new hypothesis, econometrics can be divided into two main subcategories: theoretical and applied [50].

The first step of the econometric methodology is to obtain and analyze the data set and define a specific hypothesis that explains the nature and shape of the data set. These data may be, for example, historical stock index prices, observations obtained from a survey of consumer finances, or unemployment and inflation rates in different countries.

The most common relationship is linear, meaning that any change in the explanatory variable will have a positive correlation with the dependent variable. This relationship could be explored using a simple regression model, which involves constructing a straight line that best fits two sets of data and then testing how far, on average, each data point is from that line. You can have several explanatory variables in your analysis—for example, you might use changes in GDP and inflation in addition to unemployment to explain stock market prices. If more than one explanatory variable is used, this is referred to as a multiple linear regression. This is the most commonly used tool in econometrics [51].

Econometrics is sometimes criticized for relying too heavily on the interpretation of raw data without linking it to established economic theory or looking for causal mechanisms. It is crucial that the findings revealed in the data can be adequately explained by theory, even if this means developing one's own theory of the underlying processes [34]. Econometrics is largely concerned with correlation analysis, and it is important to note that correlation does not equal causation.

An endogenous variable is a variable that is affected by changes in another variable. Because of the complexity of economic systems, it is difficult to determine all the subtle relationships between different factors, and some variables may be partly endogenous and partly exogenous.

In econometric studies, researchers must take care to account for the possibility that the error term may be partially correlated with other variables. An estimator is a statistic that is used to estimate some fact or measurement of a larger population. Estimators are often used in situations where it is not practical to measure an entire population. For example, it is not possible to measure the exact rate of employment at a particular time, but it is possible to estimate unemployment based on a randomly selected sample of the population [46, 52].

Autocorrelation measures relationships between one variable at different points in time. For this reason, it is sometimes called lagged correlation or serial correlation because it is used to measure how the past value of a variable can predict future values of the same variable [29].

EViews is an econometric software based on Microsoft Windows and is a statistical modelling and forecasting tool specializing in time series. It offers a wide range of functions for data manipulation, statistical and econometric analysis, as well as the creation of forecasts, simulations and analytical presentations of data [40]. The software works with time series, panel data or data from a longer period of time.

It facilitates efficient data manipulation, statistical and econometric analysis, forecasting or simulation [14].

4 Internal and External Cost Drivers of Individual Items in Waste Management

4.1 Distribution of Costs in Smart Technologies in the Slovak Republic

While examining the cost-effectiveness in total versus total operating costs, it is also possible to further analyze how the individual parts of the smart technology are costing relative to the whole, not only during acquisition but also during operation. Smart technologies in waste (Fig. 5) are divided into the following categories in terms of cost: hardware, software, connectivity and operation. According to waste

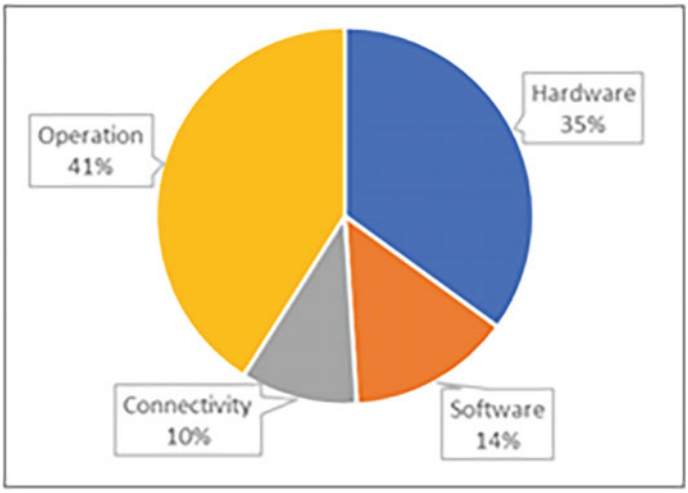


Fig. 5 Distribution of smart technologies according to the extent to which each category contributes to the cost of the waste sector in the Slovak Republic in 2021

companies, the costliest item is operation (41%), followed by hardware (35%), software (14%) and the least costly item is the cost associated with network connectivity (10%) [41, 53].

4.2 Landfill Tax Dichotomy

Due to the environmental objectives set by the European Union, it was necessary to adopt progressive charging for waste disposed of in landfills in national legislation—the Government of the Slovak Republic adopted Regulation No. 330 in 2018, which differentially charges for waste disposed of in landfills.

The chart below sets out the amount of money a municipality has to spend to landfill a ton of waste—a municipality that sorted between 40 and 50% of its waste paid a fee of EUR 7/ton in 2019, then EUR 12/ton and from 2021 it pays EUR 18/ton—an increase between 2019 and 2021 of 257.14%—the Government of the Slovak Republic is clearly financially discouraging municipalities from landfilling their waste, while at the same time incentivizing them to be more selective in the sorting of their waste and the subsequent recovery of the waste for energy use.

The following graph summarizes what fee a municipality will pay in which year (Fig. 6), according to the level of municipal waste sorting (x) [54].

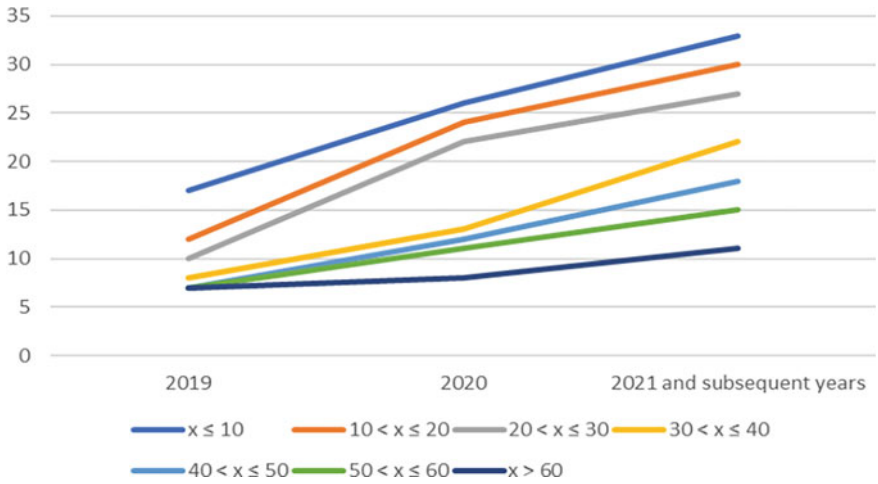


Fig. 6 Graphical summary of increasing landfill charges in relation to the proportion of waste sorted over time

5 Econometric Model and Calculation of Potential Savings with Application of Smart Technologies

5.1 Econometric Model

In this subchapter, the outputs from the econometric software EViews will be presented, with detailed statistical analysis of the individual calculations.

In the model, $R^2 = 0.99983$, i.e. very close to 1, which means that the model has a very high value, which is due to the fact that there is not a very large possibility of data in the set under study and at the same time that it is almost exclusively cost items. The equation of the econometric model thus covers almost the entire sample range [42].

Prob(F-statistic) is less than 5%, so the model is statistically significant.

The Durbin-Watson statistic has a value of 1.52—where if it were below 1.5 it would indicate the presence of positive autocorrelation and conversely, if consecutive error differences were large it would exceed 2.5 (i.e. negative autocorrelation).

In the econometric model, the variables that have the largest effect on the Wage Cost are Number of Employees (coefficient 6689) and Employees per Smart Technology (coefficient 854). Other variables that have an impact are: Municipal Waste Quantity (coefficient 2), Sorting Costs (coefficient 0.16), Information Systems Costs (coefficient 0.13) and Vehicle Costs (coefficient 0.01).

Since there is such a significant difference between the absolute values between the sum of Payroll Costs and the number of Employees per Smart Technology (Fig. 7), this was reflected in the econometric model itself. The Employees per Smart Technology variable represents the variable with the highest coefficient, and at the same

time it is almost double that of the second highest coefficient, Number of Employees. In this context, it should be noted that the wage level of employees dedicated to smart technologies is not at the level of the higher multiples of service employees [55].

The variable Wage Cost is negatively affected by: the Quantity of sorted waste (coefficient–21) and the Difference between revenue and cost of sorting (coefficient–0.19).

Variables that have probability value of 5% or less are not statistically significant—significant and therefore should not be included in the equation of the econometric model.

Dependent Variable: SALARIES

Method: Least Squares

Sample: 1 40

Included observations: 40

Variable	Coefficient	Std. Error	t-Statistic	Prob.
NUMBER_OF_EMPLOYEES	6689.338	164.0790	40.76901	0.0000
QUANTITY_ RESIDUAL_WAST	2.044168	0.602317	3.393839	0.0019
QUANTITY_ SEPARATE_WAST	-20.58769	7.662655	-2.686756	0.0115
SEPARATING_COSTS	0.161492	0.052577	3.071505	0.0044
INFORMATION_SYSTE_COSTS	0.129139	0.182308	0.708360	0.4840
PROFIT_FROM_SORTING	-0.191405	0.096680	-1.979766	0.0567
EMPLOYEES_SMART_TECH	853.4865	2360.736	0.363072	0.7190
FLEET_COSTS	0.007512	0.002641	2.844352	0.0078
C	-781149.5	63052.35	-12.38890	0.0000

R-squared	0.999830	Mean dependent var	2350372.
Adjusted R-squared	0.999786	S_D. dependent var	388573.8
S.E. of regression	5681.182	Akaike info criterion	20.32281
Sum squared resid	1.00E+09	Schwarz criterion	20.70281
Log likelihood	-397.4563	Hannan-Quinn criter.	20.46021
F-statistic	22801.88	Durbin-Watson stat	1.520518
Prob(F-statistic)	0.000000		

Fig. 7 Output from the EViews software—sorted data

Afterwards, only variables that are significant were used to see how much the coefficients and other properties of the variables change [56].

The resulting equation of the econometric model has the following form:

$$\begin{aligned} &Labor\ costs = 6,688,180 * Number\ of\ employees + 1,555,133 * Quantity\ of\ municipal \\ &waste - 20,92,232 * Quantity\ of\ sorted\ waste + 0,130,746 \\ &* Sorting\ costs + 0,008,971 * Vehicle\ costs + C \end{aligned}$$

In the resulting econometric model, the variable that has the greatest effect on the Wage Cost is the Number of Employees (coefficient 6688). The other variables that have an effect are: Quantity of municipal waste (coefficient 1.56), Sorting costs (coefficient 0.13) and Vehicle costs (coefficient 0.01).

The variable Labor cost is negatively affected by: Quantity of sorted waste (coefficient–21).

5.2 Calculation of Savings from Smart Technology Application

In Sect. 3.1 Savings Gained from the Application of Smart Technologies in Waste Management, specific examples of the application of smart technologies as well as calculated savings ranges were presented.

Based on this knowledge from practice, figures are forecasted for a period of 4 quarters, i.e. the whole year of 2022. Since the source data base is a ten-year period, only shorter data, in this case only one year, can be predicted in a qualified way [57].

Salary. The cumulative forecast for 2022 is just under EUR 12.8 million. The saving of 30% is at the level of EUR 3.8 million and the total wage costs would fall to EUR 9 million. At a 40% saving there would be a decrease of EUR 5.1 million and the total wage costs would fall to EUR 7.7 million. By analogy, the largest saving—55%—is calculated at more than EUR 7 million and the wage bill would fall to a total of just under EUR 5.8 million.

In the category of wage costs, there is a risk of a change in the minimum wage, on which the Saturday and public holiday premium is based (the premium mainly concerns service staff), which has a negative impact on wage increases beyond those agreed in the collective agreement.

Number of Employees. In calculating the employee savings, the data for Service Employees was chosen as the application of smart technology will have a greater impact in this category. Together with the smart technology application, there will be an increasing need for administrative staff to work with the data and to verify that it is up-to-date and to reevaluate the suitability of the selected container export service routes.

The average number of service staff forecasted for 2022 is 508 service staff. In the 30% savings option there would be a reduction of 152 staff to a reasonable 356 staff. If applied and a 40% savings is achieved, the need for service employees would decrease by 203 people to an average of 305 employees in the modeled year 2022.

With application achieving 55% savings, the number of service employees would decrease by 279 people to an average value of 229 service employees.

In this category, it is important to note that the crew is largely composed of one driver and two co-drivers, so the savings would be primarily among the co-drivers and only secondarily among the drivers.

Fleet costs. Fleet size and body size (a big difference in both efficiency and maneuverability), motorization and energy efficiency of vehicles (mild-hybrids or fully electric in the future) are very important factors in the calculation of predicting and potential savings in vehicle costs. The working time pool of a machine is identical to that of a driver—eight hours.

The sum of the forecasts for 2022 is EUR 13.2 million. The saving of 30% is at a level of less than 4 million Euros and the total cost of the vehicles would drop to a sum of 9.2 million Euros. At a 40% saving there would be a decrease of EUR 5.3 million and the total vehicle costs would fall to just under EUR 8 million. By analogy, the largest saving—55%—is calculated at more than 7.3 million Euros and the total vehicle costs would fall to just under 6 million Euros.

Vehicle Kilometer Mileage. Vehicle kilometer mileage is linked to the logic of service routes and there is a correlation that the greater the efficiency, the better planned are the service routes of collection vehicles, but currently these routes are planned according to fixed days of export of the selected category of waste. The application of Smart technologies would bring massive dynamism to this whole process, because when currently these routes are scheduled and re-scheduled on a quarterly basis, with Smart technologies this would be converted into a daily regular activity.

The total forecast for 2022 exceeds 1 million kilometers. The savings of 30% is at 0.3 million kilometers and the total mileage would drop to an amount exceeding 0.7 million kilometers. At a 40% saving, the decrease would be 0.4 million kilometers and the total mileage would be reduced to an amount of 0.615 km. By analogy, the largest saving, 55%, is translated to less than 0.6 million kilometers and the mileage would fall to a total of 0.46 million kilometers.

In this subchapter, based on knowledge from practice, predicted data for a period of 4 quarters, i.e. the whole period of 2022, resulting from the application of smart technologies in waste have been modelled. From the observed predictions, it can be concluded that the trend of each variable is positive, implying the benefit of savings in any application, while it is variable according to its degree.

6 Conclusion

6.1 Synopsis

Smart technologies, what elements they contain and what requirements they must meet is the content of this chapter. Based on a review of the theoretical background, it is a complex complex of interconnected relationships, where it is necessary to think far and wide about the architecture of the whole Smart City solution from the beginning, to choose software and hardware solutions appropriately and to be ready to extend the functionality with modules in the future.

The Smart City concept has been successfully applied in several cities for several years—however, it should be noted that the breadth and depth of those solutions is significantly different and therefore it is not possible to compare all cities with an applied Smart City solution 1:1, but it is necessary to clearly and in detail compare the comparative elements.

Waste management is undergoing significant transformations, especially with regard to standardization and uniformity of legislative form across the European Union, as EU mandated separation rates, landfilling and, in the future, the requirement for energy recovery cannot be ruled out. The requirements must be incorporated into national legislation in due course, and the introduction of back-up packaging within the Slovak Republic for PET bottles and ALU cans is directly linked to the fulfilment of the targets for waste sorting and landfill minimization, which are uncompromisingly close to the EU-wide level. However, there remains a very large amount of waste that does not fall into the category of backup and such waste needs to be efficiently exported and further managed, reflecting ecological and social requirements, in a purposeful and efficient manner with the least direct and indirect costs.

The study pointed to the fact that the topic of waste management, although a highly topical and important topic also within the ongoing industrial revolution Industry 4.0, is little explored and published both theoretically and practically. When the applications of Smart technologies in general in the European Union countries and the Slovak Republic are compared, the following can be clearly stated.

Namely, there are ongoing city-wide pilot projects around the world on a smaller scale, which is interesting. We can justify this interesting fact. The smaller scale is related, firstly, to people's lack of interest, the still high financial costs of introducing smart technologies and, last but not least, the unattractiveness of smart technologies in waste management. This global state of smart technology uptake in waste is incomprehensible as the waste business is highly profitable despite the high cost of smart technologies. The return on investment in smart technologies in waste is highly efficient.

Proper planning and setup for the implementation of these solutions will increase efficiency and improve the waste management sector faster and much more.

Environmental issues and related waste management are also promoted in the financial sector. In the capital market, they have higher valued assets and their shares are sold more successfully and with less risk volatility.

6.2 Further Research

As the waste management sector has so far resisted modern trends and information is difficult to understand, not to mention that it is available internally with a long-time lag and to the general public with a further time lag. In the absence of the need for digitization and application of Smart technologies from within waste management companies (with exceptions), it is clear that the use of modern technologies will only come about once the necessary legislation is in place. At the same time as such a change, there should be an obligation to introduce weighing automation across the board, including the availability of an accurate price for collection—i.e. as a ratepayer to know how full the bin was and how much it cost.

It is certainly not appropriate for Smart technologies to be applied in different areas of a collection company's operations and with different hardware/software suppliers (for interoperability reasons). As long as data is only collected without deeper analysis or operational management according to demand, it is very difficult to talk about Smart technologies [58].

The above research was carried out at the previously mentioned municipality and at the previously introduced waste treatment company. This means that the above research was not broad-based for the whole waste management sector or for several municipalities. The savings of individual items were processed on a smaller sample, due to the fact that individual municipalities do not require collection companies to implement the Smart technologies that were applied in the scientific research.

As developments have been very progressive in recent times, it can be expected that comparable research over time will yield different savings calculations, offer different Smart technologies for application or provide a different perspective on the waste management sector. Other options for developing this research are to carry it out abroad or to carry out detailed research on a waste management entity by waste management entity basis.

References

1. Oralhan, Z., Oralhan, B., Yiğit, Y.: Smart city application: internet of things technologies based smart waste collection using data mining approach and ant colony optimization. Internet Things **14**, 12–25 (2017)
2. Ortega-Fernández, A., Martín-Rojas, R., García-Morales, V.J.: Artificial intelligence in the urban environment: smart cities as models for developing innovation and sustainability. Sustainability **12**, 228–241 (2020)
3. Popa, C.L., Carutasu, G., Cotet, C.E., Carutasu, N.L., Dobrescu, T.: Smart city platform development for an automated waste collection system. Sustainability **9**, 571–593 (2017)
4. Praveen, A., Radhika, R., Rammohan, M.U., Sidharth, D., Ambat, S., Anjali, T.: IoT based smart bin: a swachh-bharat initiative. In: 2020b International Conference on Electronics and Sustainable Communication Systems (ICESC), pp. 783–786 (2020)
5. Tashev, A., Takenova, Z., Arshidinova, M.: Algorithms for solving problems of resources allocation in the management of business processes in educational organizations. Int. J. Mod. Educ. Comput. Sci. (IJMECS) **15**(5), 14–27 (2023). https://doi.org/10.5815/ijmecs.2023.05.02

6. Liu, X., Liu, G., Wan, H.-D.: Innovation of smart city management system based on computer application technology. Lect. Notes Data Eng. Commun. Technol. **122**, 333–341 (2020). https://doi.org/10.1007/978-981-19-3632-6_41
7. Fataliyev, T.K., Mehdiyev, S.A.: Integration of cyber-physical systems in e-science environment: state-of-the-art, problems and effective solutions. Int. J. Mod. Educ. Comput. Sci. (IJMECS) **11**(9), 35–43 (2019). https://doi.org/10.5815/ijmecs.2019.09.04
8. Ammar, M., Russello, G., Crispo, B.: Internet of things: a survey on the security of IoT frameworks. J. Inf. Secur. Appl. **38**, 8–27 (2018). https://doi.org/10.1016/j.jisa.2017.11.002
9. Bhandari, S.S., Thubert, P., Mani, S.: Service discovery optimization in a network based on bloom filter. US10277686B2, pp. 118–131 (2019)
10. Heal, G., Kristrцm, B.: National income and the environment. Handb. Environ. Econ. **3**, 27–43 (2005)
11. Molnár, E., Molnár, R., Kryvinska, N., Greguš, M.: Web intelligence in practice. J Ser Sci Res **6**(1), 149–172 (2014)
12. Žofčinová, V., Čajková, A., Král, R.: Local leader and the labor law position in the context of the smart city concept through the optics of the EU. TalTech J. Eur. Stud. **11**(2), 3–26 (2022). https://doi.org/10.2478/bjes-2022-0001
13. Oláh, J., Aburumman, N., Popp, J., Khan, M.A., Haddad, H., Kitukutha, N.: Impact of industry 4.0 on environmental sustainability. Sustainability (Switzerland) **12**(11), 4674 (2020). https://doi.org/10.3390/su12114674
14. Al-Masri, E., et al.: A serverless IoT architecture for smart waste management systems. In: 2018 IEEE International Conference on Industrial Internet (ICII), pp. 179–180 (2018)
15. Poniszewska-Maranda, A., Kaczmarek, D., Kryvinska, N., Xhafa, F.: Studying usability of AI in the IoT systems/paradigm through embedding NN techniques into mobile smart service system. Computing **101**(11), 1661–1685. ISSN: 0010–485X (print version), ISSN: 1436–5057 (electronic version) (2019). https://doi.org/10.1007/s00607-018-0680-z
16. Fedushko, S., Peráček, T., Syerov, Y., Trach, O.: Development of methods for the strategic management of web projects. Sustainability **13**, 742 (2021). https://doi.org/10.3390/su13020742
17. Kaczor, S., Kryvinska, N.: It is all about services—fundamentals, drivers, and business models. J. Ser. Sci. Res. **5**(2), 125–154 (2013)
18. Poniszewska-Maranda, D., Kaczmarek, N.K., Xhafa, F.: Studying usability of AI in the IoT systems/paradigm through embedding NN techniques into mobile smart service system. Computing **101**(11), 1661–1685 (2019). https://doi.org/10.1007/s00607-018-0680-z
19. Fedushko, S., Ustyianovych, T., Gregus, M.: Real-time high-load infrastructure transaction status output prediction using operational intelligence and big data technologies. Electronics **9**(4), 668 (2020). https://doi.org/10.3390/electronics9040668
20. Government of the Slovak Republic: Environmental Policy Strategy of the Slovak Republic up to 2030. https://www.minzp.sk/iep/strategicke-materialy/envirostrategia-2030.html
21. Ministry of Environment of Slovak Republic: Waste Prevention Programme of the Slovak Republic 2019–2025. https://www.minzp.sk/files/sekcia-enviromentalneho-hodnotenia-riadenia/odpady-a-obaly/registre-a-zoznamy/ppvo-sr-19-25.pdf
22. Cajková, A., Jankelová, N., Masár, D.: Knowledge management as a tool for increasing the efficiency of municipality management in Slovakia. Knowl. Manag. Res. Pract. (2021). https://doi.org/10.1080/14778238.2021.1895686 (in press)
23. National Council of the Slovak Republic: Act No 79/2015 on waste and amending certain acts, as amended, and amending certain acts. https://www.slov-lex.sk/pravne-predpisy/SK/ZZ/2015/79/20220101.html
24. Pardini, K., et al.: A smart waste management solution geared towards citizens. Sensors **20**(8), 42–58 (2020)
25. CISCO: The internet of things reference model (2014). http://cdn.iotwf.com/resources/71/IoT_Reference_Model_White_Paper_June_4_2014.pdf
26. Beer, S.: Diagnosing the System for Organizations. John Wiley, London New York (1985)

27. de Barros Chapiewski, G., Quintana, M., Kumar, M., Lettau, T., Patterson, W.: User intervention based on tracking device location. US10002515B2 (2018)
28. Anthopoulos, L.: Smart utopia VS smart reality: learning by experience from 10 smart city cases. Cities **63**, 128–148 (2017)
29. Bajaj, R., Ranaweera, S.L., Agrawal, D.P.: GPS: location-tracking technology. Computer **35**(4), 92–94 (2002). https://doi.org/10.1109/MC.2002.993780
30. Shlyakhetko, O., Syerov, Y., Gregus, M.: Model of smart locating application for small businesses. Electronics (Switzerland) 12 (2023). https://doi.org/10.3390/electronics12091993
31. Androniceanu, A., Popescu, C.R.: An inclusive model for an effective development of the renewable energies public sector. Administratie si Manag. Public **2017**(28), 81–96 (2017)
32. Baum, D.: Grundlagen der Warteschlangentheorie. Springer, Berlin (2013). https://doi.org/10.1007/978-3-642-39632-8
33. Ross, S.: Random variables. In: Introduction to Probability Models, pp. 34–76. Elsevier (2014). https://doi.org/10.1016/B978-0-12-407948-9.00002-5
34. Hanes, D., et al.: IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things, pp. 62–81. Cisco Press, Indianapolis, USA (2017)
35. Farooq, M., Waseem, M., Khairi, A., Mazhar, S.: A critical analysis on the security concerns of internet of things (IoT). Int. J. Comput. Appl. **111**, 5–23 (2015)
36. Vinod Kumar, B., Sangeetha, J.: A smart IoT device for child's safety real time monitoring system. Int. J. Inf. Eng. Electron. Bus. (IJIEEB) **15**(6), pp. 64–77 (2023). https://doi.org/10.5815/ijieeb.2023.06.05
37. Kryvinska, N., Kaczor, S., Strauss, C., Greguš, M.: Servitization—its raise through information and communication technologies. In: Snene, M., Leonard, M.: Exploring Service Science, Lecture Notes in Business Information Processing. Springer, Berlin Heidelberg, pp. 72–81 (2014)
38. Huseynova, A., Mazanova, O.: Development of the smart city concept in Azerbaijan. Int. J. Inf. Technol. Comput. Sci. (IJITCS) **15**(3), 55–64 (2023). https://doi.org/10.5815/ijitcs.2023.03.05
39. Weinstein, R.: RFID: a technical overview and its application to the enterprise. IT Profess. **7**(3), 27–33 (2005)
40. Perkins, C.E.: Network address management for a wired network supporting wireless communication to a plurality of mobile users. US5159592A (1992)
41. Höjer, M., Wangel, J.: Smart sustainable cities: definition and challenges. In: Hilty, L.M., Aebischer, B. (eds.) ICT Innovations for Sustainability, pp. 333–349. Springer International Publishing, Advances in Intelligent Systems and Computing (2015)
42. Iamtrakul, P., Klaylee, J.: Creating a prototype smart city for a case of developing world: Pathum Thani, Thailand. GMSARN Int. J. **17**(1), 67–75 (2021)
43. Chowdhury, B., Chowdhury, M.U.: RFID-based real-time smart waste management system. In: 2007 Australasian Telecommunication Networks and Applications Conference, pp. 175–180 (2007)
44. Jin, J., Gubbi, J., Marusic, S., Palaniswami, M.: An information framework for creating a smart city through internet of things. IEEE Internet Things J. **1**(2), 112–121 (2014)
45. Holubčík, M., Jandačka, J., Trnka, J.: Closed cycle of biodegradable wastes in smart cities. In: EAI/Springer Innovations in Communication and Computing, pp. 59–73 (2022). https://doi.org/10.1007/978-3-030-92968-8_4
46. Dameri, R.P.: Searching for smart city definition: a comprehensive proposal. Int. J. Comput. Technol. **11**(5), 2544–2551 (2013)
47. University of Vienna. Benützung—Fachbereichsbibliothek Wirtschaftswissenschaften und Mathematik. Retrieved January 19, 2021, from https://bibliothek.univie.ac.at/fb-wirtschaftmathematik/benuetzung.htm
48. Schaffers, H., Komninos, N., Pallot, M., Trousse, B., Nilsson, M., Oliveira, A.: Smart cities and the future internet: towards cooperation frameworks for open innovation. In: Domingue, J., Galis, A., Gavras, A., Zahariadis, T., Lambert, D., Cleary, F., Daras, P., Krco, S., Müller, H., Li, M.-S., Schaffers, H., Lotz, V., Alvarez, F., Stiller, B., Karnouskos, S., Avessta, S., Nilsson, M.

(eds.) The future internet. Lecture Notes in Computer Science, pp. 431–446. Springer, Berlin Heidelberg (2011)
49. Batty, M., Axhausen, K.W., Giannotti, F., Pozdnoukhov, A., Bazzani, A., Wachowicz, M., Ouzounis, G., Portugali, Y.: Smart cities of the future. Eur. Phys. J. Spec. Top. **214**(1), 481–518 (2012)
50. Maphosa, V.: Sustainable e-waste management at higher education institutions' data centres in Zimbabwe. Int. J. Inf. Eng. Electron. Bus. (IJIEEB) **14**(5), 15–23 (2022). https://doi.org/10.5815/ijieeb.2022.05.02
51. Dragoni, N., Giallorenzo, S., Lafuente, A.L., Mazzara, M., Montesi, F., Mustafin, R., Safina, L.: Microservices: yesterday, today, and tomorrow. In: Mazzara, M., Meyer, B. (eds.) Present and Ulterior Software Engineering, pp. 195–216. Springer International Publishing, Cham (2017)
52. Google OR-Tools: Vehicle Routing Problem (2021). https://developers.google.com/optimization/routing/vrp
53. Rana, S., Verma, J., Gautam, A.K.: A comprehensive study with challenges of internet of things (IoT) based model for smart farming. Int. J. Educ. Manag. Eng. (IJEME) **12**(4), 43–53 (2022). https://doi.org/10.5815/ijeme.2022.04.05
54. Vacca, J. (ed.): Handbook of Sensor Networking: Advanced Technologies and Applications. Chapman and Hall/CRC (2015)
55. Baumgarten, C., Ivanochko, I.: The impact of electronic services on traditional services. In: Developments in Information & Knowledge Management for Business Applications. Studies in Systems, Decision and Control, vol. 330. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-62151-3_7
56. ISO 37120: 2018 Sustainable Cities and Communities–Indicators for City Services and Quality of Life (2018)
57. Jedrzejewska, M., Zjawiński, A., Karovič, V., Ivanochko, I.: Cloud CRM system for mobile virtual network operators. In: Barolli, L., Nishino, H., Miwa, H. (eds.) Advances in Intelligent Networking and Collaborative Systems (INCoS 2019). Advances in Intelligent Systems and Computing, vol. 1035. Springer, Cham. https://doi.org/10.1007/978-3-030-29035-1_39
58. Mohanty, S.P., Choppali, U., Kougianos, E.: Everything you wanted to know about smart cities: the internet of things is the backbone. IEEE Consum. Electron. Mag. **5**(3), 60–70 (2016)

Smart Energy Components—Foundation of a Decentralised Energy Supply

Alexander Neubaur

Abstract This paper explores the concept of "smart energy" as a pivotal element in achieving an intelligent and decentralized energy supply. The term encompasses various energy generation, storage, power transmission, and consumption control technologies. The transition from centralized to decentralized power generation introduces challenges to grid stability, requiring innovative solutions. The paper emphasizes the importance of smart grids, smart meters, and smart homes in dynamically managing energy consumption and generation. It discusses the components of smart energy and the integration of information and communication technologies (ICT) in creating an "Internet of Energy." Additionally, the paper addresses hurdles such as the smart meter rollout, grid stability, sector coupling, energy efficiency, dynamic tariff design, and energy storage. The role of Power-To-X processes and the potential of different storage technologies, including compressed air storage and Power-To-Gas, are explored. The paper concludes by highlighting the need to overcome these hurdles to establish a functional smart energy system and ensure a successful energy transition.

Keywords Energy transition · Smart energy · Electricity system · Grid stability · System stability · Grid expansion · Electricity grid financing

1 Explanation of Terms

The term "smart energy" is used to summarise various components that will be necessary for the intelligent control of the future, increasingly decentralised energy supply.[1] This includes "all intelligent technologies for energy generation, energy storage, power transmission and consumption control. The entire value chain from

[1] Cf. Servatius, Schneidewind et al. [2].

A. Neubaur (✉)
Comenius University Bratislava, Bratislava, Slovakia
e-mail: neubaur1@uniba.sk

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2024

P. Štarchoň et al. (eds.), *Data-Centric Business and Applications*, Lecture Notes on Data Engineering and Communications Technologies 213,
https://doi.org/10.1007/978-3-031-62213-7_15

power generation to power consumption is thus addressed. Smart terms have been coined for some of these technologies in recent years. For example, the term smart grid stands for intelligent electricity transmission and distribution, while the terms smart metering and smart home stand for the control of consumer behaviour."[2]

2 Motivation

The change from centralised power generation in power plants to decentralised power generation poses various problems for the existing distribution and transmission grids. Due to the large number of small power generators feeding into the grid, it is relatively difficult for the grid operator to estimate how much electricity will be fed into the grid and when. Since it is easy to forecast the electricity demand of the consumers in his grid area on the basis of standard load profiles or existing load profiles for RLM customers, it was previously no problem to have the corresponding amount of electricity provided by the power plants and thus to ensure grid stability. However, due to the unpredictability of the amount of wind and photovoltaic energy fed into the grid, enormous surpluses or deficiencies of electrical power can quickly influence the grid frequency in the distribution grid. In the worst case, this can lead to a large-scale grid failure, as almost happened in the European interconnected grid on 08.01.2021, for example.[3] In this case, the use of renewable energies was not the cause, but the effects on grid stability are the same due to sudden large-scale loss of power, e.g. due to clouds or no wind.

In order to keep the grid frequency stable, the amount of active power generated must correspond as closely as possible to the amount of power consumed at any given time. An oversupply of power leads to an increase in the grid frequency and an undersupply to a decrease. In Europe, the grid frequency is 50 Hz throughout the country, which means that the voltage in the grid changes 50 times per second from zero to the specified voltage in the positive range, then to the same voltage in the negative range and then back to zero (Figs. 1 and 2).

"In order to keep the grid frequency stable, control energy is needed. If the frequency falls below 50 Hz, additional feed-in or load shedding (the reduction of consumption) is needed, which is called positive control energy. If the grid frequency is too high, the feed-in must be reduced, which is also called negative control energy. In Germany, the transmission grid operators are responsible for grid regulation and the associated procurement of control energy.

If the grid frequency drops to 49.8 Hz, power reserves from all power plants in the interconnected grid are used. If the grid frequency continues to fall below 49 Hz, so-called load shedding occurs. In this case, selected areas are disconnected from the electricity grid so that electricity consumption is reduced. From a frequency of

[2] Cf. (2022) https://www.itwissen.info/Smart-Energy.html.

[3] Cf. (2022) https://www.entsoe.eu/news/2021/07/15/final-report-on-the-separation-of-the-continental-europe-power-system-on-8-january-2021/.

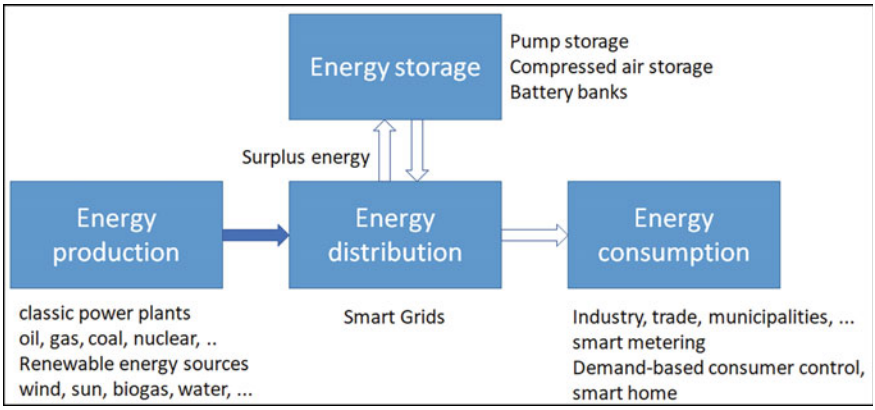


Fig. 1 Components of the smart energy concept[4]

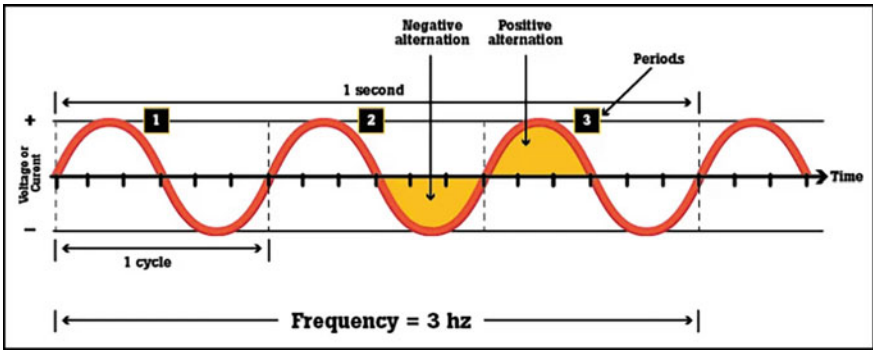


Fig. 2 Frequency[5]

47.5 Hz, all power plants are disconnected from the grid and the power supply is then rebuilt.

If the grid frequency rises above 50 Hz, the power plants reduce their feed-in power. This takes longer for older coal-fired and nuclear power plants. Renewable energy plants, such as wind power or photovoltaic (PV) plants, can adapt more quickly. From a grid frequency of 50.02 Hz, the majority of PV plants reduce their active power linearly and only from an overfrequency of 51.5 Hz is there a complete disconnection of the plants from the grid."[6]

[4] Cf. Neubaur, A. (2022), based on https://www.itwissen.info/Smart-Energy.html, own presentation and translation.

[5] Cf. (2022) https://www.fluke.com/de-de/mehr-erfahren/blog/elektrik/was-versteht-man-unter-frequenz.

[6] Cf. (2022) https://www.interconnector.de/wissen/netzfrequenz/.

In the end, the motivation of all measures is to ensure a stable supply of electricity. To achieve this, it is necessary to be able to react quickly and intelligently to fluctuations in feed-in and consumption so that there are no disruptions in the distribution network. The situation-dependent switching on and off of consumers and feed-in plants is the cornerstone for this. Only if it is ensured that a correspondingly large number of consumers can be dynamically controlled by a central monitoring point can the challenges of the future be successfully mastered. The increasingly complex determination of what has to be switched on and off due to the use of renewable energies, as well as the higher dynamics within these monitoring and switching processes, can only be successfully implemented with the support of information technology-supported systems. The goal of this successful control is ultimately also the key to the acceptance of the energy transition within the population, which is already reduced to a certain degree due to the strongly rising energy prices.

3 Components of Smart Energy and the Internet of Energy

In order to successfully make the energy transition a reality, a control system supported by "information and communication technologies" (ICT) is needed. This control system should make it possible to intelligently generate, store, distribute and consume the electricity generated by renewable energy production so that electrical energy is always available where it is needed. This control system consists of various components that play their role in the different areas of energy supply. The BMWi's publication "Smart Energy made in Germany" states: "The ICT-optimised operation of distribution grids, the networking of consumers and producers as well as new marketplaces and business scenarios were the focus of interest. The ICT solutions developed and tested in E-Energy help pave the way for an "Internet of Energy" in which decentralised producers communicate with each other as well as with the electricity grids and consumers—in the technical sense and as market participants".[7]

The central component of the smart energy concept, i.e. the intelligent energy system, is the smart grid, the intelligent energy supply system. The term smart grid describes the networking of intelligent generation plants and consumers, as well as energy storage systems and grid operating equipment, i.e. electrical components of distribution and transmission grids that are necessary for the operation of these grids, such as transformers, instrument transformers, protective devices[8] and many others. The components mentioned form the energy supply system as a known form of the energy supply network. The energy information system (EIS), which gives the energy supply system its intelligence, is responsible for networking these components of the smart grid using information and communication technologies (Figs. 3 and 4).

[7] Cf. (2022) https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/smart-energy-made-in-germany.pdf.

[8] Cf. (2022) https://www.enargus.de/pub/bscw.cgi/d1225-2/*/*/Betriebsmittel.html.

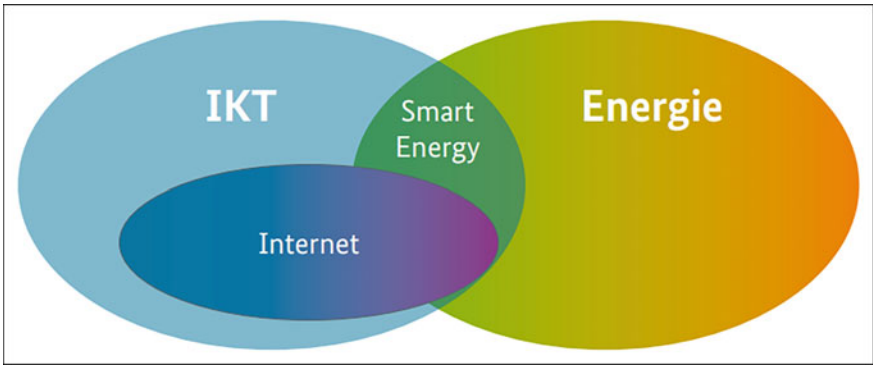


Fig. 3 Relationship between the domains energy, ICT and internet[9]

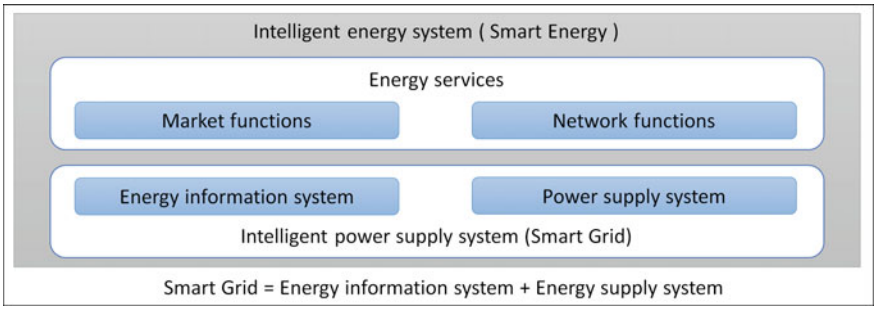


Fig. 4 Components of smart energy[10]

This energy information system in turn consists of the grid automation system and a service platform. The grid automation system has the task of automatically regulating the grid frequency by switching controllable consumers and feed-in plants on or off in the appropriate quantity. The service platform also provides an overview and control interface for other market participants who want to control their customers' intelligent consumers or generators. In this context, these components are called intelligent "if they can optimally adapt to the current supply conditioned by the market and the grid. They are connected to the overall system via intelligent communication devices."[11]

[9] Cf. (2022) https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/smart-energy-made-in-germany.pdf.

[10] Cf. Neubaur, A. (2022), based on https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/smart-energy-made-in-germany.pdf. p. 5, own presentation and translation.

[11] Cf. (2022) https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/smart-energy-made-in-germany.pdf.

Regarding the acceptance of the end customers to allow this control of their consumers and producers, Andreas Kamper writes: "Participation in a load management system causes a certain effort for the participants (e.g. by connecting the appliances to or specifying the characteristics of the appliances for the control), which in many cases is associated with a loss of comfort (e.g. the laundry is done later). In addition, the necessary infrastructure in the household must be provided by the customers (e.g. the automation system or the internet connection). Participants must therefore be offered incentives to participate in such a system. These can be, for example, ecological or economic incentives, but also legal requirements. Since the total amount of energy used remains the same in a pure load shift, it must be ensured that the participant does not incur higher costs due to the shift in energy use. This could occur, for example, when using time-variable tariffs, if appliances are shifted into a time range where higher prices have to be paid by shifting the appliance use."[12]

The medium-term availability of smart meters at consumption and generation plants in Germany offers a basis for these switching services due to their networking and the IT security they provide. However, it is currently assumed that due to low switching flexibility, another device will take over the control of individual consumers, the energy manager. These energy managers "receive information about current prices, the generation mix or the conditions in the grid and can use this to switch end devices on or off and report the resulting flexibilities to aggregators, distributors or other market participants, who can improve their consumption forecasts in this way. The intelligence of the energy managers must be such that they only control devices when their operating status allows this in a meaningful way. In this respect, there will only be hard control signals in the Internet of Energy for extreme exceptional conditions. Otherwise, the control devices will receive offers, so to speak, which they can accept but also reject."[13]

One of various conceivable scenarios for such a component structure in the Internet of Energy is shown in the following figure (Fig. 5).

Here, the data from the individual smart meters is transmitted via a gateway to a data warehouse, which also includes the data from field measuring devices that monitor the condition of the distribution network. Both the grid operator and the other market roles have access to the part of this data that is relevant to them. The network operator then has, for example, to analyse the consumption of individual installations in the event of an undersupply in the distribution network and could then send information to the corresponding controlling market role that consumption is to be reduced here, provided that the end consumer has generally contractually agreed to this intervention. As described above, this is initially considered an offer, which the controlling market role then sends to the gateway of the energy manager in the object, which then intelligently decides to what extent a disconnection of individual consumers is currently possible and sensible, and acts accordingly.

[12] Cf. (2022) Kamper [1], p. 71.

[13] Cf. (2022) https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/smart-energy-made-in-germany.pdf.

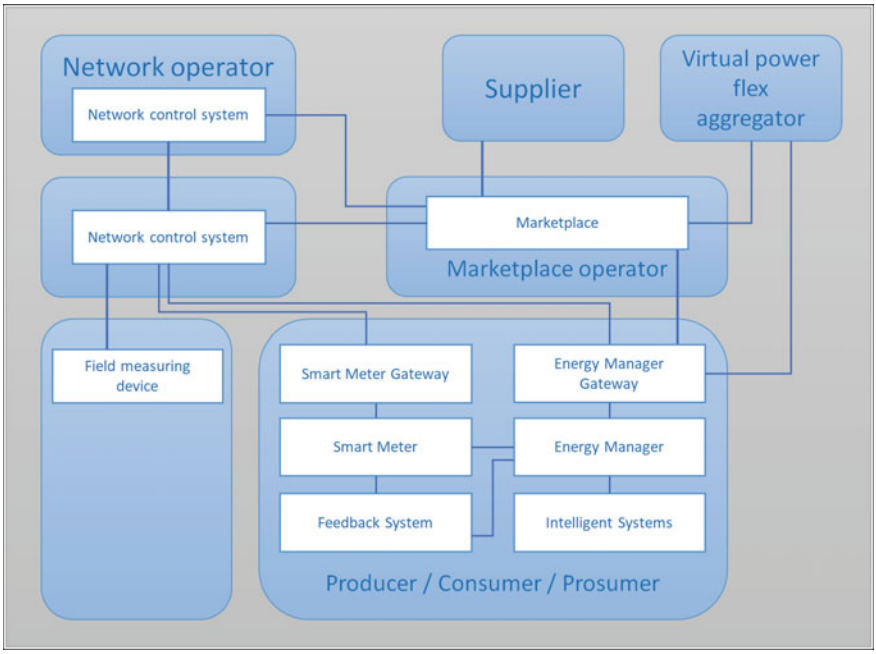


Fig. 5 Components in the Internet of Things[14]

The marketplace represents the various established market roles, such as supplier and network operator, but also new market roles such as virtual power plant aggregators, which combine a large number of feed-in plants to form a virtual power plant, or the connection user's energy service provider (ESA), which will obtain metered values from the metering point operator and process them for the connection user as a new market role in Germany from 1 October 2022.

Depending on the design of the system, the energy manager also proactively establishes a connection to the data warehouse and obtains consumption data from smart meters, network status data from field measuring devices, wholesale prices for electricity or weather data and uses these to determine an optimal consumption, storage and feed-in schedule for the corresponding object.[15]

In this scenario, smart energy management combines the terms marketplace, flexibility management and object management. While flexibility management coordinates the activities of several objects and, in a cellular approach, also manages these cells and thus acts as an aggregator.

"Flexibility management receives information from electricity sales, e.g. current electricity prices (for generation and consumption), and from grid operations on the

[14] Cf. Neubaur, A. (2022), based on https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/smart-energy-made-in-germany.pdf p. 57, own presentation and translation.

[15] Cf. (2022) https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/smart-energy-made-in-germany.pdf.

status in the grid—usually with the aim of having a stabilising effect. Flexibility management forms suitable signals from this information and transmits them to suitable objects, where they are intelligently processed by object management and converted into suitable switching signals for generation or consumption devices or storage.[16]

As long as the overall system is in the green or yellow area (see traffic light model), price signals are sent to all or suitable objects and a decision is made by way of negotiation (e.g. first-come, first-served) as to who accepts offers or satisfies requests. In this process, the object management decides together with the device control whether switching on or off is possible at the current time. In the best case, sufficient generators or consumers are switched in such a way that they help to stabilise the grid. If the system is in a red state, the grid transmits special requirements to the energy management system in the building. These are passed on—without further optimisation algorithms, but on the same communication paths as the other signals—to generators and consumers defined for this purpose that can be interrupted or switched on."[17]

The term "smart home" and the home control components that go with it can also play a decisive role in this scenario, as the concepts under consideration are based on the fact that consumption and generation systems in buildings can be controlled in order to stabilise the grid or not contribute to destabilisation in the first place (Fig. 6).[18]

In an integrated, intelligent system, all the object management systems (OMS) of large feed-in plants such as wind turbines, solar parks or conventional power plants, as well as the OMS of large industrial consumers, buildings, building complexes, etc., are then connected to the grid. Directly connected to the grid operation in order to be able to stabilise the grid by switching command in case of a problem. In normal grid operation, the behaviour desired by the grid control system is influenced by economic or ecological incentives via flexibility management. This intelligently regulates whether a consumer is operated now or later, whether the electricity required for this is drawn from the PV system, from the home storage system, from the storage system of the electric car or from the distribution grid. In this way, energy consumption and the efficiency of use within distribution grids can be significantly improved.

[16] Cf. (2022) https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/smart-energy-made-in-germany.pdf.

[17] Cf. (2022) https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/smart-energy-made-in-germany.pdf

[18] Cf. (2022) https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/smart-energy-made-in-germany.pdf.

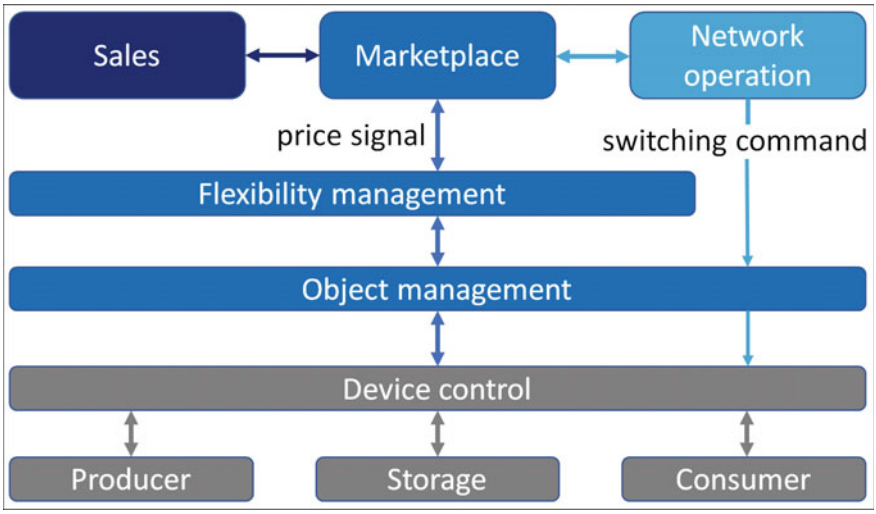


Fig. 6 Market-driven energy property management[19]

4 Hurdles

As was already evident from the previous chapters, there are still some hurdles that need to be overcome in order to commission and successfully operate a functioning smart energy system.

4.1 Smart Meter Rollout

"On 31.01.2020, the Federal Office for Information Security (BSI) determined the "technical feasibility of installing smart metering systems in accordance with Section 30 of the Metering Point Operation Act (MsbG)", also known as the market declaration. This marks the beginning of the legal obligation to roll out smart metering systems by 24.02.2020 by the responsible metering point operators. A decisive cornerstone has thus been laid for the efficient implementation of the energy transition."[20]

Since 2020, all electricity meters replaced by rotation in Germany will be replaced by modern metering devices (mME), which means that these mMEs are to be installed in all households by 2032. According to the current legal situation, only every modern metering device that exceeds an annual consumption of 6000 KWh is to be equipped

[19] Cf. Neubaur, A. (2022), based on https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/smart-energy-made-in-germany.pdf. p. 59, own presentation and translation.

[20] Cf. (2022) https://www.bdew.de/energie/digitalisierung/welche-rolle-spielen-smart-meter-fuer-die-digitalisation-of-the-energy-transition/.

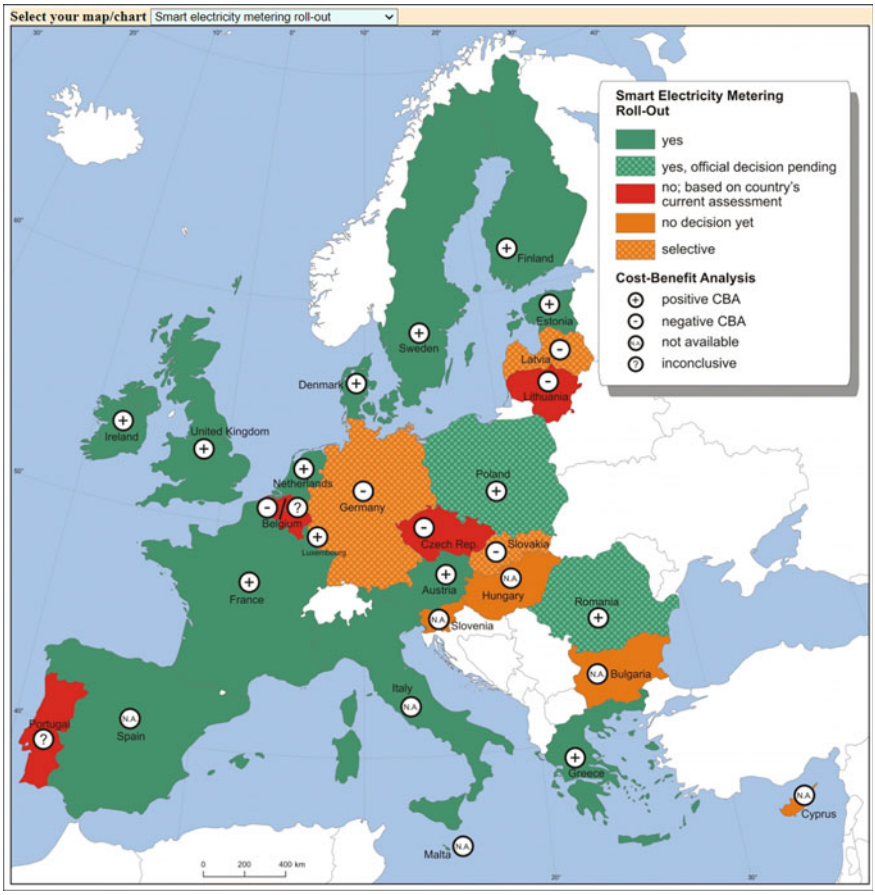


Fig.7 Smart electricity metering roll-out[22]

with a smart meter gateway, whereby these mMEs will be upgraded to smart meters. Consumption points with a lower consumption can be equipped with smart metering systems on a voluntary basis.[21]

The expansion of smart meters is also being started in many other European countries, which supports a general standardisation of the European electricity grid (Fig. 7).

[21] Cf. (2022) https://www.bdew.de/energie/digitalisierung/welche-rolle-spielen-smart-meter-fuer-die-digitalisation-of-the-energy-transition/.

[22] Cf. (2022) https://ses.jrc.ec.europa.eu/sites/ses.jrc.ec.europa.eu/files/files/map2.html.

4.2 Grid Stability/System Stability

Ensuring a stable energy supply is the central challenge of the energy transition, which is ultimately served by all new, intelligent components.

Grid stability requires system services (frequency maintenance, voltage maintenance, supply restoration, operation management), which are still mainly provided by conventional power plants. The trend assumes that in the future not only flexible generation plants, but also consumers and storage facilities will increasingly contribute to the stabilisation of the grids. The measures and processes for system stabilisation must be continuously developed and coordinated at regional and European level.[23]

In order to ensure this stability, in addition to the possibility of being able to intelligently switch consumers and generators, an improvement in the forecasting accuracy of consumption and generation is also essential. Taking weather data into account, such forecasts are already being made today, but the impact on the available electricity in the grid will increase with the greater expansion of renewable energies. To overcome this problem, especially in the case of a shortfall, energy balancing should come from storage facilities and, if necessary, from the generation plants of other EU countries. In order to enable this transnational planning and control, an EU legal framework is needed. This framework and the available measures were presented in the concept of the European Green Deal in 2019. This is intended to provide financial resources to further advance the expansion of the so-called Energy Union.[24]

4.3 Sector Coupling

"Sector coupling is about connecting the energy sector with the industry, transport and building sectors and then optimising them together. If all sectors are interconnected, the idea goes, then CO_2 emissions can be reduced with the help of renewable energies. In the process, storage technologies can balance out the volatile renewables."[25]

Sector coupling can be divided into two basic strategies. The first is electrification, i.e. the conversion of final energy consumers that are traditionally powered by fossil fuels to the use of electrical energy that can be fed by renewable energy sources in the future. In concrete terms, this means a further expansion of electromobility and the replacement of oil and gas-fired building heating systems with electric heat pumps. To this end, further incentives must be created to promote the expansion of these technologies, for example through financial support. The second strategy describes the Power-To-X process. Here, synthetic or biogenic fuels such as

[23] Cf. (2022) Quote: https://www.bmwk.de/Redaktion/DE/Artikel/Energie/strom-2030-trend-10.html.

[24] Cf. (2022) http://library.fes.de/pdf-files/wiso/11468.pdf.

[25] Cf. (2022) https://www.ewi.uni-koeln.de/de/themen/sektorenkopplung/.

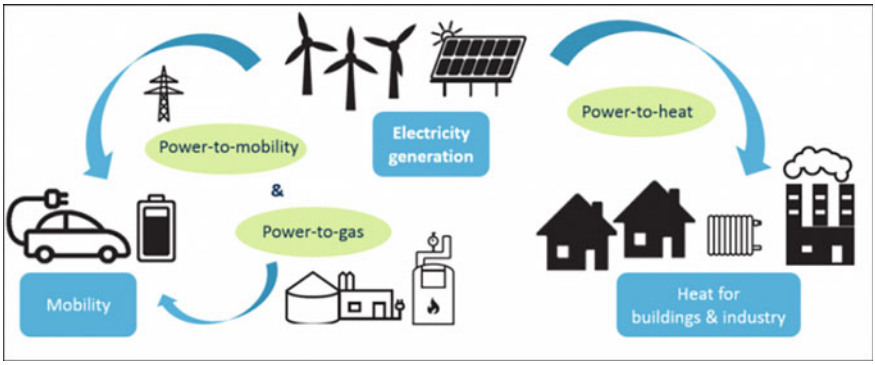


Fig. 8 Sector coupling[27]

hydrogen, methane, petrol or paraffin are generated from surplus electricity in order to supply energy consumers with renewable energy where electrification is currently not possible, such as air traffic (Fig. 8).[26]

The generation of these fuels through electricity means that significant energy losses have to be accepted, but existing ones can be used, such as gas grids, district heating grids or petrol stations. One of the tasks ahead is to push ahead with these Power-To-X processes and thus make sensible use of the surplus electricity from renewable energy in order to make the energy transition a success.

4.4 Energy Efficiency

Increasing energy efficiency is one of the leading topics of the energy transition. Under the motto "efficiency first", the Federal Ministry for Economic Affairs and Energy published the "Green Book on Energy Efficiency" in 2016, in which various measures are presented to reduce the primary energy demand in Germany by half by the year 2050. The motivation for this is as simple as it is comprehensible: "A unit of energy that can be saved does not have to be generated, stored and transported."[28] This topic is therefore one of the main pillars of the energy transition and is particularly relevant for the success of the entire project.

The big picture includes, in addition to increasing the efficiency of electrical appliances through EU requirements, the thermal insulation of buildings, the use of heat pumps for heating, but also increasing efficiency in industrial processes. One challenge here is to prevent certain direct and indirect rebound effects, which can

[26] Cf. (2022) https://www.ewi.uni-koeln.de/de/themen/sektorenkopplung/.

[27] Cf. (2022) https://www.cleanenergywire.org/factsheets/sector-coupling-shaping-integrated-renewable-power-system.

[28] Cf. (2022) https://www.bmwk.de/Redaktion/DE/Publikationen/Energie/gruenbuch-energieffizienz-august-2016.pdf.

occur, for example, when financial resources freed up by lower energy consumption are used for more energy elsewhere. In order to counteract these effects, political control mechanisms via quantity, price and legal regulations are being discussed.[29]

4.5 Dynamic Tariff Design

The spread of dynamic electricity tariffs presupposes the widespread use of smart intelligent metering systems. Only then is it possible for the electricity supplier to use the load profiles or meter readings provided by the iMSys to identify at which quarter-hour interval the consumer has drawn which amount of electricity. For example, this consumption can be compared with the stock exchange price and thus a different price can be realised in different time intervals. In addition to the stock exchange price, other price signals are also conceivable, such as the currently available power in the electricity grid, so that the price increases if balancing energy has to be used within the balancing group.

In order for the end consumer to be able to actively influence the cost of his electricity, he must know exactly when electricity will cost him how much. This could be controlled in a relatively uncomfortable way via a timetable that the energy supplier provides to the end customer so that he can schedule his consumers accordingly. It would make much more sense to have an intelligent control system that takes over this switching when a corresponding price or other situation gives the signal to do so. However, such a control system requires corresponding devices, as well as a control unit that can receive the corresponding signals, interpret them and forward them to the end devices. This scenario is difficult to realise on a nationwide basis in the near future.[30]

4.6 Energy Storage

So while there is an overall overproduction of electricity in Germany, some of which has to be exported for free or for a fee in order to relieve the electricity grid, the share of cost-intensive coal-fired electricity continues to increase. The reason for this is that the excess electricity is generated in the warm season, when wind and sun are abundant, while at the same time consumption is low. This electricity is then also exported, although there is no high demand for energy abroad during this time,

[29] Cf. (2022) https://www.bmwk.de/Redaktion/DE/Publikationen/Energie/gruenbuch-energieffizienz-august-2016.pdf.

[30] Cf. (2022) https://www.wsw-online.de/happy-power-hour/wissensbereich/wie-funktioniert-ein-dynamischer-electricitytariff.

which is why this surplus then partly burdens the grid of the countries supplied. The Federal Ministry of Economics and Environmental Protection writes (2018):

> "Unlike apples and many products, electricity absolutely needs a consumer, as it cannot simply be "disposed of" and can also only be stored in small quantities. In addition, the power grid is only stable if feed-in and withdrawal are exactly in balance. In short: the electricity must be used—if necessary, even at a negative price. This is not a new phenomenon, but has been observed on the power exchange since September 2008. At that time, negative electricity prices were allowed—also at the request of many market participants—as an incentive for conventional power plants to adjust their electricity production to the fluctuating demand and weather-dependent generation from renewable energies."[31]

Thus, in order to increase the share of renewable energies in gross electricity consumption, a possibility of shifting between generation and consumption must be created (Fig. 9).

The solution to this is energy storage, which can first be differentiated into categories of storage duration[32]:

1. Short-term memory

Power memory (seconds to minutes)

- High performance to storage capacity ratio
- for short-term fluctuations
- especially for grid services/control power
- Use several times per day
- especially batteries, capacitors, flywheel accumulators.

Shift memory (minutes to hours)

- Especially for balancing within one day (for example PV self-consumption)
- one to two cycles per day
- Especially batteries, compressed air storage, pumped storage power plants (PSW).

2. long-term memory (days to weeks)

- for long-term slack periods/seasonal storage/back-up
- Few cycles per year
- Chemical storage (hydrogen/methane) and large storage hydropower plants (for example in Norway).

As described here, battery storage systems are particularly useful for storing electricity for short periods of time, from seconds to hours. They are being used more and more in buildings to be able to use the surplus solar power generated during the day at night. For this purpose, storage capacities of just a few kilowatt hours (5 to

[31] Cf. (2022) https://www.bmwi-energiewende.de/EWD/Redaktion/Newsletter/2018/02/Meldung/direkt-explained.html.

[32] Cf. (2022) https://www.bmwk.de/Redaktion/DE/Textsammlungen/Energie/speichertechnologien.html.

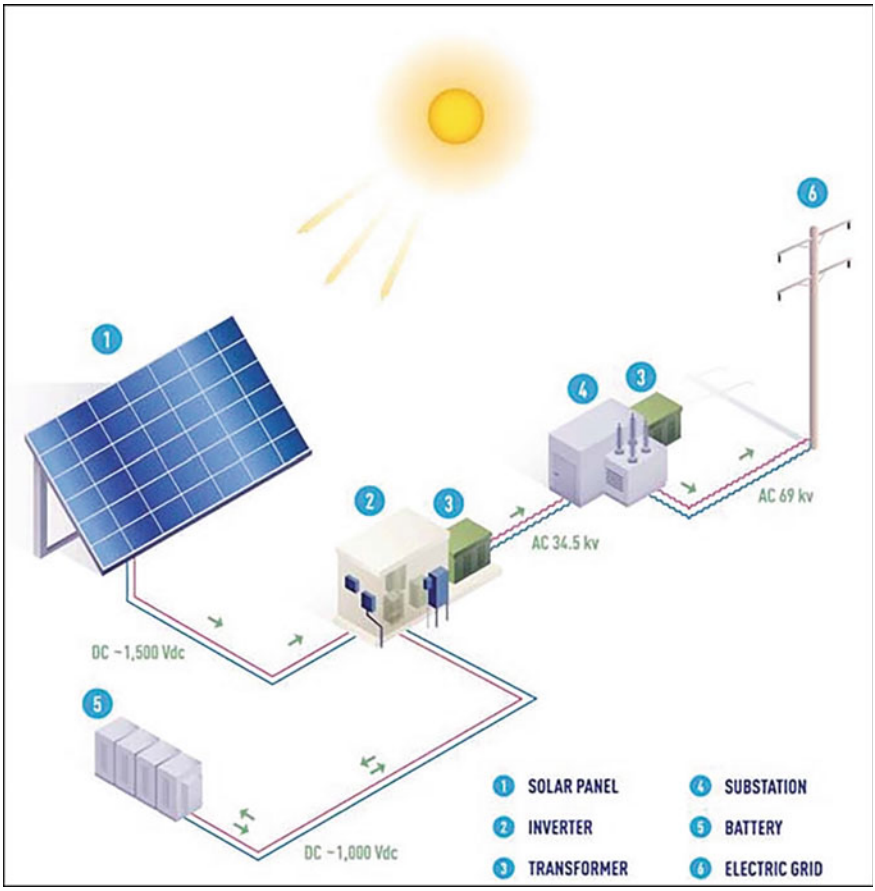


Fig. 9 Example of a battery storage-supported photovoltaic system[33]

10) are usually useful, as a high degree of self-sufficiency can be achieved in this way during the warm half of the year.

Large storage units can be charged without any problems in summer, but the energy consumption in the few hours without sunlight is usually not sufficient to empty large storage units. In winter, on the other hand, the size of the battery storage unit in the home is of secondary importance, since even the largest storage unit is quickly empty when there is little sunlight and heavy cloud cover, and one is also dependent on the supply from the distribution grid.

It is interesting to note that the two energy sources, photovoltaics and wind power, complement each other very well, which is why the necessary storage capacity can be significantly smaller if wind and solar power plants are combined into combined

[33] Cf. (2022) https://www.mauinews.com/news/local-news/2020/09/two-solar-power-battery-storage-projects-are-submitted-to-puc/.

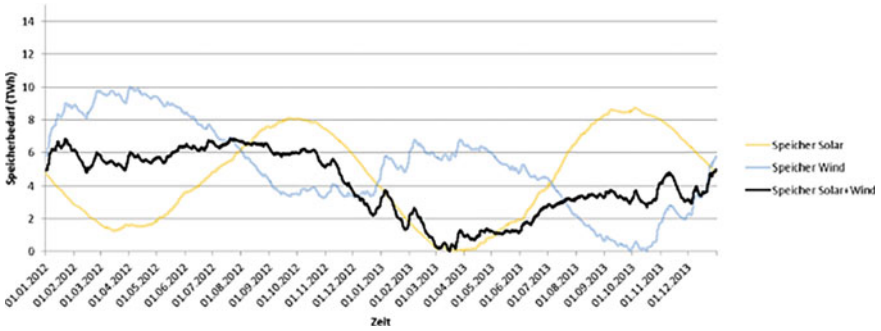


Fig. 10 Storage requirements for the stabilisation of photovoltaics and wind power[35]

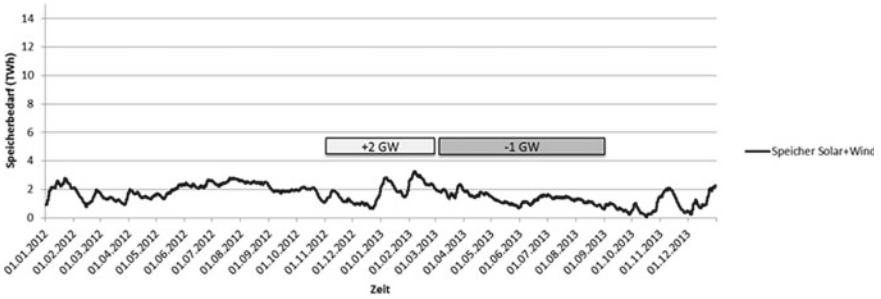


Fig. 11 Storage requirements for the stabilisation of photovoltaics and wind power with minimal use of controllable generation[37]

cycle power plants. For the stabilisation of solar power in Germany alone, about nine terawatt hours of storage capacity would be needed, for wind power even ten terawatt hours. If these power generators are combined, this requirement is already reduced to 6.3 terawatt hours to ensure a constant flow of electricity (Fig. 10).[34]

The combined black line shows only relatively small fluctuations, which is why storage systems can be filled over months and emptied again over months. Rapidly reacting storage systems are therefore not needed to any great extent here. Accordingly, in this case, if electricity production were increased by two gigawatts in the months of November to March and poduction were reduced by one gigawatt between April and August, the storage requirement would already be reduced to two terawatt hours (Fig. 11).[36]

Thus, three terawatt hours of storage capacity would be sufficient to provide solar and wind power equally as a conventional power plant does. Nevertheless, three

[34] Cf. (2022) https://sma-sunny.com/wie-viel-speicher-braucht-die-energiewende.
[35] Cf. (2022) https://sma-sunny.com/wie-viel-speicher-braucht-die-energiewende.
[36] Cf. (2022) https://sma-sunny.com/wie-viel-speicher-braucht-die-energiewende.
[37] Cf. (2022) https://www.sma-sunny.com/wie-viel-speicher-braucht-die-energiewende.

terawatt hours is an enormous amount, which of course continues to increase with the steady expansion of solar and wind power. This means that we are still dependent on large storage options that can be charged in summer and discharged in winter.

In order to store large amounts of surplus electrical energy produced in the summer for the dark season, batteries are not economical due to the high costs. To store very large amounts of energy, physical storage systems such as pumped storage or compressed air storage have a clear advantage. Even though pumped storage power plants are technically mature and the only storage technology that can currently be used in Germany on a significant scale, the storage capacities of all German pumped storage power plants with a storage capacity of 0.085 terawatt hours[38] are not sufficient to cover the demand.

When planning a European solution that includes large photovoltaic plants in Spain, large storage hydropower plants in Norway could also be used for storage. A capacity of 1.4 gigawatts can be transmitted via the NordLink submarine cable, which connects Germany and Norway.[39] This way, enormous overloads in the German electricity grid could be used to fill Norway's water reservoirs in the summer and then return this energy in the winter.

In order to continue to increase the potential of energy storage despite the lack of expansion options in the area of water storage in Germany, research is also being conducted into compressed air storage and power-to-gas plants. While pumped storage power plants have been used worldwide for decades, there are currently only two compressed air storage facilities in operation worldwide, one of which is located in Germany.

Here, ambient air compressed to 70 bar is stored in a salt dome about 500 m deep, in two compressed air caverns with a total volume of 300,000 m^3, to be released again as needed by an electricity-generating generator. Since the plant dates back to the 1970s, its efficiency is well below today's standards. More than 50% of the energy is lost through storage, which is why researchers are trying to find a solution to increase efficiency.

New turbines and an exhaust gas heat exchanger, which captures the heat generated during the compression of the air and thus warms up the air cooled by the expansion, are to help here in order to prevent the generators from icing up. In current plants, this heating is achieved by burning natural gas, which is why an additional loss of efficiency is unavoidable here (Fig. 12).[40]

Another very promising solution for storing surplus energy is the generation of methane, the so-called Power-To-Gas process. Here, surplus electricity is first converted into hydrogen by electrolysis and, depending on the requirement, subsequently converted into methane. The great advantage here is that the gas produced

[38] Cf. (2022) https://www.sma-sunny.com/wie-viel-speicher-braucht-die-energiewende.

[39] Cf. (2022) https://www.ingenieur.de/fachmedien/bwk/energieversorgung/norwegen-ist-deutschlands-largest-battery/.

[40] Cf. (2022) https://www.deutschlandfunk.de/tolle-idee-was-wurde-daraus-druckluftspeicher-fuer-100.html.

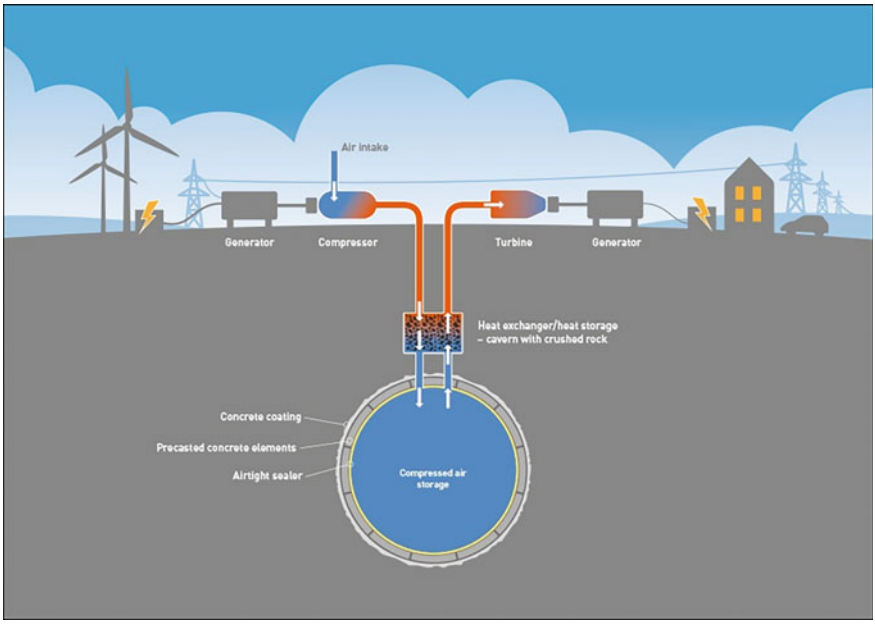


Fig. 12 Compressed air reservoir[41]

in this way (hydrogen within certain limits, methane without restrictions) can be fed into the existing natural gas grid and stored in existing gas storage facilities.

For example, the methane produced can be used together with methane produced from biomass in order to convert it back into electricity when needed or to use it for other applications, such as heating or for operating gas-powered vehicles. However, since this multiple conversion leads to high losses, Power-To-Gas is not yet an economically viable alternative.[42]

Nevertheless, there are already operating plants in Germany, such as the electrolysis plant in Wunsiedel, Bavaria, which will officially open in September 2022. This six-megawatt plant will produce up to 13,550 tonnes of green hydrogen per year in the future.[43] Most of the green hydrogen produced in this way is to be transported by truck trailer to industrial and commercial enterprises in the region that need it for their production processes. In addition, some of it will be available for hydrogen-powered vehicles at an H_2 filling station directly at the energy park (Fig. 13).[44]

As can be seen from the existing plants, this technology is already operational and the resulting product is very versatile. The gas produced can be used in the already

[41] Cf. (2022) https://www.sintef.no/en/latest-news/2017/air-could-be-the-worlds-next-battery/.

[42] Cf. (2022) https://www.bmwk.de/Redaktion/DE/Artikel/Energie/gas-power-to-gas.html.

[43] Cf. (2022) https://www.br.de/nachrichten/bayern/bald-ohne-gas-energiezukunft-spielt-in-wunsiedel.

[44] Cf. (2022) https://www.chemietechnik.de/energie-utilities/produktion-fuer-gruenen-wasserstoff-startet-in-wunsiedel-170.htm.

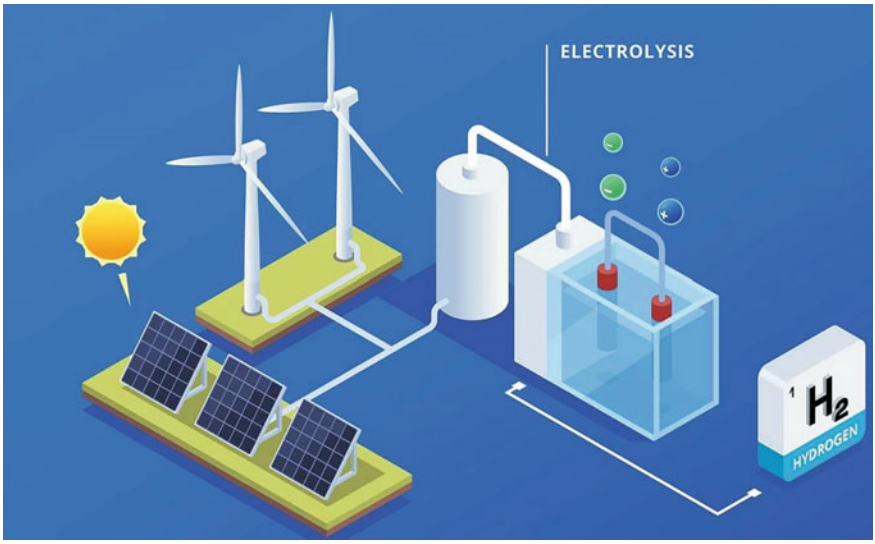


Fig. 13 Power-to-gas via electrolysis[45]. *Author* Alexander Neubaur

existing infrastructure of the natural gas grid and can therefore provide a great benefit to the energy supply in Germany.

References

1. Kamper, A.: Dezentrales Lastmanagement zum Ausgleich kurzfristiger Abweichungen im Stromnetz (2022)
2. Servatius, H., Schneidewind, U., et al.: Smart Energy. Transformation to a Sustainable Energy System. Springer, Berlin/Heidelberg (2011). ISBN 978-3-642-21819-4

Bibliography

3. https://www.awattar.de/tariffs/hourly, own translation
4. https://www.bdew.de/energie/digitalisierung/welche-rolle-spielen-smart-meter-fuer-die-digitalisierung-der-energiewende/
5. https://www.bmwi-energiewende.de/EWD/Editorial/Newsletter/2018/02/Message/direct-erklaert.html
6. https://www.bmwk.de/Redaktion/DE/Artikel/Energie/energiedaten-gesamtausgabe.html
7. https://www.bmwk.de/Redaktion/DE/Publikationen/Energie/gruenbuch-energieffizienz-august-2016.pdf
8. https://www.bmwk.de/Redaktion/DE/Artikel/Energie/gas-power-to-gas.html

[45] Cf. (2022) https://solarenergie.de/hintergrundwissen/solarenergie-nutzen/sektorenkopplung/power-to-gas.

9. https://www.bmwk.de/Redaktion/DE/Dossier/netze-und-netzausbau.html
10. https://www.bmwk.de/Redaktion/DE/Textsammlungen/Energie/speichertechnologien.html
11. https://www.mecs-press.org/ijisa/ijisa-v15-n1/v15n1-4.html
12. https://www.bmwk.de/Redaktion/DE/Artikel/Energie/strom-2030-trend-10.html
13. https://www.bmwi.de/Redaktion/DE/Dossier/energieforschung-und-innovation.html
14. https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/smart-energy-made-in-germany.pdf
15. https://www.br.de/nachrichten/bayern/bald-ohne-gas-energiezukunft-spielt-in-wunsiedel
16. https://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/Sachgebiete/Energie/Unternehmen_Institutionen/NetzentwicklungUndSmartGrid/ZustandAusbauVerteilernetze2020.pdf
17. https://www.bundesregierung.de/breg-de/themen/klimaschutz/novellierung-des-eeg-gesetzes-2023972
18. https://www.chemietechnik.de/energie-utilities/produktion-fuer-gruenen-wasserstoff-startet-in-wunsiedel-170.htm
19. https://www.cleanenergywire.org/factsheets/sector-coupling-shaping-integrated-renewable-power-system
20. https://www.deutschlandfunk.de/tolle-idee-was-wurde-daraus-druckluftspeicher-fuer-100.html
21. https://www.dvgw.de/themen/energiewende/sektorenkopplung
22. https://www.enargus.de/pub/bscw.cgi/d1225-2/*/*/Supplies.html
23. https://www.enercity.de/magazin/unsere-welt/funktionsweise-power-to-heat
24. https://www.ewi.uni-koeln.de/de/themen/sektorenkopplung/
25. https://www.faz.net/aktuell/finanzen/stromversorgung-in-deutschland-drohen-im-winter-stromausfaelle-18336929.html
26. https://www.ingenieur.de/fachmedien/bwk/energieversorgung/norwegen-ist-deutschlands-groesste-batterie/
27. https://www.itwissen.info/Smart-Energy.html
28. https://www.itwissen.info/Smart-Energy.html, own presentation and translation
29. https://www.iwr.de/news/forscher-testen-energiespeicher-mit-superkondensatoren-news35104
30. http://library.fes.de/pdf-files/wiso/11468.pdf
31. https://www.mauinews.com/news/local-news/2020/09/two-solar-power-battery-storage-projects-are-submitted-to-puc/
32. https://www.merkur.de/wirtschaft/deutschland-strom-winter-preise-blackout-sorge-netzbetreiber-news-analyse-91809160.html
33. https://www.net4energy.com/wiki/bruttostromerzeugung
34. https://www.presseportal.de/pm/75892/2051150
35. https://ses.jrc.ec.europa.eu/sites/ses.jrc.ec.europa.eu/files/files/map2.html
36. https://www.sciencedirect.com/science/article/pii/S0306261917317889
37. https://www.sintef.no/en/latest-news/2017/air-could-be-the-worlds-next-battery/
38. https://www.sma-sunny.com/wie-viel-speicher-braucht-die-energiewende
39. https://solarenergie.de/hintergrundwissen/solarenergie-nutzen/sektorenkopplung/power-to-gas
40. https://www.strom-forschung.de/aktuelles/news/2021/innovative-turbomaschinen-mit-wasserstoff-betreiben

41. https://www.umweltbundesamt.de/sites/default/files/medien/479/publikationen/texte_27-2022_nachhaltige_nutzung_erneuerbarer_energien_in_effizienten_gebaeuden_und_quartieren.pdf
42. https://www.umweltbundesamt.de/themen/klima-energie/erneuerbare-energien/erneuerbare-energien-in-zahlen#ueberblick
43. https://www.vaillant.de/21-grad/rat-und-tat/energiespeicher/
44. https://www.wsw-online.de/happy-power-hour/wissensbereich/wie-funktioniert-ein-dynamischer-stromtarif

The Concept of Smart Cities—An Accelerator of the Circular Economy

Vojtech Kollár and Silvia Matúšová

Abstract More than two thirds of the population of the European Union live in cities. They consume about 80% of energy and produce up to 85% of European gross domestic product, but they are also significant producers of waste and high consumption of products. Cities have become centres of innovation, new technologies, and the source of many challenges that the Union faces, from environmental pollution to social inequalities. Cities and regions are the most prominent contributors to persistent economic and environmental problems. Cities, however, offer new and more effective solutions for a better quality of life for inhabitants. The most efficient cities could be named intelligent cities, i.e., Smart Cities. Regional policy must become an accelerator of the growth of the innovative performance of cities and regions with a focus on key areas such as research, development and innovation, the business environment and the use of the potential and resources of cities and regions. Innovations, together with innovation policy, are conditioning the degree of technical and technological equipment of the region's economy and thus complete a complex of mutual relations that cumulatively shape and become the organizational structure, and a parameter of the development of cities and regions.

Keywords Smart cities · Regional policy · Innovation · European union · Sustainable solutions · Urban development

1 Introduction

Today, more than two thirds of the population of the European Union (EU) live in cities. They consume about 80% of energy and produce up to 85% of EU gross domestic product, but they are also significant producers of waste and high consumption of products [11]. Cities have become centres of innovation, new technologies, but also a source of many challenges. Cities and regions are the most prominent

V. Kollár (✉) · S. Matúšová
Bratislava University of Economics and Management, Furdekova 16, Bratislava, Slovak Republic
e-mail: vojtech.kollar@vsemba.sk

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2024

P. Štarchoň et al. (eds.), *Data-Centric Business and Applications*, Lecture Notes on Data Engineering and Communications Technologies 213,
https://doi.org/10.1007/978-3-031-62213-7_16

contributors to ongoing economic or environmental problems, but cities offer new and more effective solutions for a better quality of life for people. Today, we can call these most efficient cities intelligent cities, i.e., Smart Cities [4, 45].

Regional policy must become an accelerator of the growth of the innovative performance of cities and regions with focus on supporting key areas such as research, development and innovation, the business environment and the use of the potential and resources of cities and regions. Innovations together with innovation policy condition the level of technical and technological equipment of the region's economy and thus complete a complex of mutual relations that cumulatively shape and become the organizational structure, as well as a parameter of the development of cities and regions [15].

2 Methodology of the Research

The aim of the chapter is to analyse and assess innovations that have become a factor of the development in cities and regions with a focus on Smart City projects, key areas of public policies, the green economy, the area of quality education, the development of science, research, and innovation, ensuring health, building effective public administration and the use of digitization.

The concept of smart cities makes it possible to connect all components, such as transport, energy, waste management and road infrastructure, which will help build a cleaner environment for residents and increase the quality of life.

In the first part, we focused on the area of innovation, which is the engine of the development of the city and the region and represents the core of the Smart City concept, and we listed the key areas that are monitored by the index of the city's level of intelligence. In the second part, we focused on the implementation of the Smart City concept in the regions of Slovakia, especially in the Prešov region. Our intention was to point out that the idea of a smart city can be developed and implemented in a border region that does not rank among the best developing ones in terms of its economic indicators.

In the paper, we used the methods of analysis and synthesis, comparison, and generalization. We used the analysis in relation to the scientific literature related to smart cities in the context of circular economy and applied the synthesis when summarizing the information from the strategic, political, and conceptual materials approved at the European, national and regional level. The aim of this approach was to point out that the development of smart cities is primarily connected innovation, its support in the development of regions, both related to regional policy, human resources development in regions, education markets and labour markets in the context of the advancing circular economy in the Slovak Republic.

The contribution of the study lies in the fact that it pointed out the possibilities of adoption and the implementation of the idea of smart cities as centres of innovation and education, while not focusing on the capital or regional cities, but on a district city in the least developed region of Slovakia.

We proceeded methodically from the definition of innovations, the survey of scientific literature to the topic, which waw supplemented with the analysis of primary data, the application of secondary data, followed by the assessment of results concerning the implementation of the concept of smart cities and regions.

3 Innovation as an Engine of City and Region Development

Innovations have become a phenomenon of regional development. The analysis of the European Innovation Index 2022 indicates, the Slovak Republic was rated above the EU average, based on indicators concerning technologies related to the environment, air pollution, and the export of medium and high-quality goods.

Indicators with a below-average rating of the Slovak Republic within 30% of the European Union average relate to lifelong learning, expenditure on risk capital, government support for business, research and development, expenditures related to research and development within the business sector, product innovators and business innovators in small and medium-sized businesses, labour mobility in HRST and, finally, patent applications [24].

3.1 Innovation—The Core of the Smart City Concept

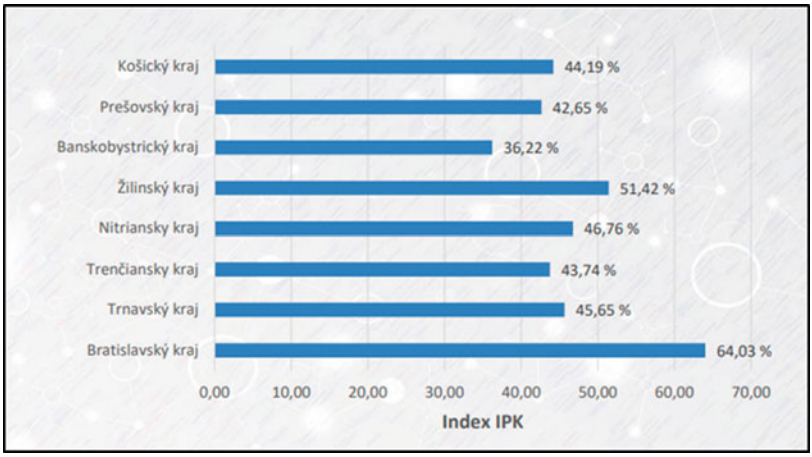
Innovations are defined as the successful creation, introduction, and use of novelties in the economic and social spheres, the renewal and expansion of the range of products and services and their associated markets, the creation of new methods of production, supply, distribution, the introduction of changes in management, work organization, working conditions and the qualifications of work forces [26]. Innovations are often referred to as the driving engine of economic development. But innovations are also a way to improve the quality of life, support sustainable solutions, attract talents, increase competitiveness, and increase GDP.

In the case of Slovak regions, their innovation performance is assessed according to the IPK (Innovation Potential of Regions) index, which includes 5 domains: People and cooperation, Politics and funding, Infrastructure, Culture and conventions, and Economic performance. Table 1 shows the innovation potential of individual regions of the Slovak Republic.

Bratislava region has the highest innovation potential (64.03%) and Banská Bystrica region has the lowest (36.22%). The Bratislava region is a moderate innovator. Its innovative performance increased over time (3.5%).

Western Slovakia is a moderate innovator. The innovation performance of the region increased over time (2.8%). Central Slovakia is a moderate innovator and its innovation performance decreased over time (−5.1%). Eastern Slovakia is a moderate innovator, and its innovation performance has increased over time (6.6%) [39].

Table 1 Innovation potential of Slovak regions (2021)



Source SIEA [39]

Slovakia is at the level of 81% in the Regional Innovation System (RIS) assessment of lifelong learning. Slovakia has maintained the best achieved score in the indicator of trademark applications, at the level of approximately 76% of the EU average. This area is an important innovation indicator for the sector of services.

Patent applications are the worst rated indicator. In this indicator, Slovakia fell below 80% of the EU average. In 2021, the Slovak Republic achieved the worst rating in the monitored period, even though it belongs to the new innovators. It does not even reach 70% of the EU average. In comparison, the Czech Republic is the best rated country within the Vyšehrad Four countries (V4), consisting of Poland, Czech Republic, Hungary and Slovakia. The Czech Republic reached the 17th place within the V4 in the European innovation ranking in 2021, and the Slovak Republic reached the 23rd place. In the dimension of digitization, the Slovak Republic reached more than 80% of the EU average. The Slovak Republic achieved the worst result in the assessed area of funding and support, where it reached 30.4% [24].

The EU Horizon Europe program for research and innovation for the years 2021–2027, allocated a budget of 95.5 billion € which can help countries achieve environmental and digital transformation. As part of the cohesion policy, more than 56.8 billion € is invested to research and innovation capacity, digitization and skills and support of innovation and green economic transformation in European regions.

Better performance in all four areas (favourable environment, human capital, markets, and innovation) requires eliminating regional disparities in EU countries and shape better competitiveness and environmental sustainability, security and shared prosperity.

Effective cooperation at the national, regional, and European level is necessary to create a strong innovation system. According to the European Innovation Scoreboard 2022, Slovakia, and several countries from the Central and Eastern European region

such as Poland, Hungary, Latvia, and Croatia are ranked in the last places of the charts, with an increasingly widening gap between the leaders and the European average. Slovakia ranks as the 6th worst country in the EU in terms of investments in research and development. In the assessment of brain drain Slovakia achieves the second worst results. As a reaction to this result, the National Strategy for Research, Development and Innovation 2030 was adopted by the Slovak Government, with clear goals and milestones, for example achieving a significantly higher rating in the European Innovation Scoreboard or attracting 25 thousand highly qualified people from abroad to Slovakia.

3.2 Modern Technologies in the Smart City Concept

The Smart City concept focuses on the use of modern technologies and innovative solutions to improve the living standards of residents and efficient city management. However, the Smart City concept is not only about technology. It also includes active cooperation between local authorities, the private sector, and residents. It ensures transparency, participation, and involvement of residents in the decision-making process and increases the quality of life in the city. The Smart City concept also creates opportunities for the development of new technologies and innovations in areas such as information and communication technologies, energy, transport, environmental technologies, and many others [38].

The cities of the future [44] will bring their residents a new quality of life, which will, however, depend on the quality of the environment and the smart use of resources, a smart economy aimed at the prosperity of the region and the participation of smart communities.

The use of Smart solutions in urban areas includes many possibilities. The basis of proper functioning in cities belongs to the communication, in which full coverage of services is not always ensured, because there are still places where access to the Internet is very slow. The creation of smart cities requires an overall and complex approach of the parties involved [17].

The creation of smart cities is a process that involves various factors such as urbanization, demographic changes, cultural aspects and economic development. A city is a place where people live and work, and its success and effectiveness depend on how well these various factors align. Many factors must be considered when creating cities. The construction of the city must be planned in such a way that it is efficient, sustainable, and adapted to the needs of the inhabitants. The city must have high-quality and sufficient transport connections, medical facilities, schools, and other basic services. It must also have sufficient water and energy reserves and at the same time minimize the negative impact on the environment.

We can present the concept of Smart City as a connection of innovative solutions focused on municipality (self-government in the city) and state administration. The concept of Smart City consists of components that imply institutional capacities and

governance available to residents and businesses and could participate in activities supporting innovation in cities.

The Smart City concept focuses on six areas such as energy and environment, mobility, buildings, governance and self-administration, health, and education. A Smart City can contain various components that aim to improve the quality of life of residents and make the city work more efficiently.

The Smart City Index is applied to assess the level of city's intelligence, i.e., the quantity and quality of services and technologies that the city provides to its residents and visitors. The index, as the first global assessment instrument of Smart cities, assesses urban areas based on the perception of residents. The way of how residents perceive the extent and the impact of efforts of the municipality to make their city smart is assessed based on economic and technological aspects.

In 2017, the International Institute for Management Development (IMD) and the Singapore University of Technology and Design (SUTD) decided to join forces to create a smart cities index that offers a balanced focus on the technological and economic aspects of smart cities, where on the one hand the "human dimension" of smart cities was included and on the other hand, the index included the quality of life and the environment, as well as inclusion [18].

There are several types of Smart City indices, which differ according to their focus and the criteria applied (see Table 2).

The baseline tracking index is used to measure how well an organization, business or municipality can focus on and track its goals. The benchmark tracking index helps determine whether the organization is moving in the right direction and, if not, allows you to quickly change tactics and improve the situation. The indexes should always be designed so that they can be measurably quantified, compared and analysed.

The concept of Smart City emphasizes the principle of integrated development, which will apply the most effective cross-sectional solutions for experimental development and innovation and for building smart cities in the Slovak Republic. Among the key challenges, which aroused interest in the development of Smart City solutions, include a combination of economic, technological, and social changes to which the municipality must respond. In addition to innovations, the need to make these

Table 2 Basic criteria for Smart City assessment

Area	Meaning
Smart economics	The rate of use of digital technologies in business and economy
Smart mobility	Improving mobility and transport systems, as well as the use of information technology to improve traffic
Smart environment	Assessment of the environmental sustainability and environmental protection measures
Smart human resources	Assessment of the quality of education and health care in the city
Smart governance	Assessment of the level of digitization of public administration and interaction between citizens and local authorities

Source Own processing

changes is also brought about by the densification of urban development, the aging of the population, higher pressure on public finances, as well as an increasing emphasis on the environmental aspects of everyday life [41].

The introduction of the smart city concept also brings other benefits, e.g., that every resident in the city can get a job, to access to infrastructural services, to use reliable and low-cost energy sources, to access to adequate education opportunities, to use available forms of housing and efficient transport. City residents are given access to the resources they need to provide for future generations. Sustainability is not only linked to the environment, but also to the economy. Smart cities effectively use natural resources, human capital, and economic resources [27].

In a smart city, residents have access to a healthy and clean, safe, comfortable, and active lifestyle, they can use convenient public transport, faster public services, they also have access to various entertainment and cultural events. The Smart City infrastructure consists of three basic pillars. They include smart mobility, smart energy, smart services, information and communication technologies [40]. These functional ecosystems can be realized through strategies that help cities achieve their goals in a sustainable way.

In all pillars it is possible, for example, to introduce information and communication tools and innovative solutions that will improve aspects of the lives of residents in the city or in the region [10].

To implement intelligent solutions, it is therefore necessary to apply an integrated approach at the level of the city self-government or at the level of the catchment region, across all dimensions. Only in this way the services with high added value can be provided to the target group. Regarding the urban development, technologies represent a tool for meeting growing social needs. People should use them in ways that lead to a better quality of their lives. However, a smart city should not be perceived only in relation to the use of modern technologies. The goal of building and developing a smart city is the growth of quality in all areas in relation to the population. A change in attitude and behaviour is important.

From a technological point of view, data and information have a special position, which is constantly shaping the city. Everyday challenges associated with the entire society (especially the aging population, loss of intergenerational understanding, constantly increasing demands for mobility, quality, and availability of services, etc.) require a constant search for solutions, the aim of which is the development of the city as a complex mechanism [3].

The concept of a smart city therefore requires an approach that is aimed at building a sustainable community, which is based on the principle of smart management. At the same time, it is necessary to maintain a balance between economic, social, and environmental aspects and to find intelligent solutions that will positively influence the further development of the overall urban ecosystem.

The basis for the start of the Smart City processes and services is the safe and transparent collection and analysis of data that can affect key aspects of public services and quality of life [38]. The goal is to increase the efficiency of the services provided.

One of the important aspects enabling this transformation is the targeted use of ICT, which can provide decision-making bodies at the city level with up-to-date

information on the state of the infrastructure in terms of traffic permeability, energy wastage or monitoring the necessity of repairs. This creates a monitoring system that further enables the efficient allocation of available resources and their release at less demanding times. This information is obtained through sensors embedded in critical locations in combination with direct input from residents [6].

The combination of inputs should make it possible to eliminate the main points of waste of available resources and to better focus on the priorities of the public administration in the planning of public services. The management and regulation of traffic in the city includes cycling, and traffic with the help of traffic telematics, administrative measures, and the planned development of the city's transport infrastructure.

An important tool in this case is the European methodology of Sustainable Urban Mobility Plans (SUMP). One of the most affected by the development of smart technologies in practice is the field of personal transport. The inhabitants of the city therefore have more options than ever before thanks to modern technologies. These options also apply to personal transport, as well as the transport of goods, including delivery services. One of the key aspects is the development of the shared economy through mobile applications, which bring entrepreneurs and SMEs direct contact with potential customers.

Applications in the field of transport thus helped to increase the awareness of customers about available alternatives to classic car transport through taxi service providers and alternative means of transport. As part of urban sustainable mobility, the priority of the Smart City is to reduce and avoid the demand for transport options that cause high emissions with increased mobility of citizens, goods, and information.

Therefore, the main pillar of the smart city project is to build intelligent management and regulation of traffic in the city, including bicycle traffic, in terms of energy. Another project is the construction of environmentally demanding modes of transport that pollute the environment less. As part of the infrastructure for sustainable urban areas and the environment of buildings, it is necessary to improve the energy efficiency of buildings by using renewable energy sources. For example, the green infrastructure of the city will consist of urban and suburban greenery, which will be complemented by the grey infrastructure of buildings. Greenery will have urban, architectural, climatic, and ecological benefits. Energy, and energy infrastructure constitute one of the basic pillars of the Smart City concept [40].

In this area, smart solutions will concern the improvement of the traffic management system and the optimization of the traffic flow, the creation of intelligent multimodal transport solutions, efficient parking systems, the provision of peer-to-peer transport information, and the construction of a city information platform. Furthermore, the infrastructure for waste management, the dynamic management of energy resources with standard and renewable resources will also be created and used.

Other projects will concern public lighting or the connection of monitoring devices that serve to provide warning signals in the city. By incorporating innovations into the blockchain of smart city, it will be possible to create a cross-cutting platform that will connect various Smart City networks and services to each other, especially with a high degree of security and transparency in all processes [44].

These solutions will try to contribute mainly to the improvement of work in local self-government, support territorial planning or contribute to the development of the economy. The Internet of Things will continue to transform residents into a super-connected society. Artificial intelligence, big data analysis, augmented reality and robotics are really becoming a part of our everyday life these days.

3.3 Smart City Support Strategy

In 2010, the "Europe 2020 Strategy" was adopted by the European Council, with the objective to increase the growth potential of the EU countries and ensure a high level of employment [43]. The stated strategy aimed to help Europe recover from the crisis and transform it into an intelligent, inclusive, and sustainable economy with a high level of employment and productivity, social cohesion, and the European Union tried to strengthen itself in global governance, where the EU became the main actor.

To speed up the processes related to connecting cities, industry and citizens, the European Commission initiated the platform European Innovation Partnership on Smart Cities and Communities, which connects sectors, cities and citizens and focuses on integrated urban solutions, via ICT and by means of overall solutions for environmental, health and social challenges. This initiative followed the Smart Cities and Communities initiative from 2011 and covered the areas of transport, energy, and ICT. The main focuses are on sustainable urban mobility, sustainable urban districts and building environments, and integrated infrastructure and processes, local solutions within the EU and global markets [8, 12].

The main goals include the introduction of modern methods, the effective use of natural resources and energy sources, the transfer of knowledge from research and development, and technology into practice, the production of new and improved products and services, the development of entrepreneurial activity in the field of development and innovation. In this connection, intelligent regions in cooperation with Slovak companies and foreign companies should be developed. On May 19, 2011, the Territorial Agenda of the European Union 2020 was approved at an informal meeting of the ministers responsible for territorial planning and territorial development [48].

The goal of the agenda is to support polycentric and balanced territorial development, to ensure development in the countryside, in cities and specific regions, where the main goals of support were focused on the development of working conditions, on improving the quality of life of residents and on improving public and social services for residents and businesses. Among the key goals were, for example, modernization of the primary sector through investments that use alternative sources of sectors such as agriculture and forestry, where the areas of maintaining the quality of arable land and its ecological functions have become equally key.

Other goals include the increase of the research and its contribution to the creation of an innovative society as well as the improvement of the quality of human resources for an innovative Slovakia.

3.4 The Indexes of Smart Cities Development

In 2017, the International Institute for Management Development (IMD) and the Singapore University of Technology and Design (SUTS) joined forces to create the Smart Cities Index. The first edition of the IMD Smart City Index was carried out in 2019 by the IMD World Competitiveness Centre's Smart City Observatory in collaboration with SUTD. The first top 10 cities included 1. Singapore, 2. Zurich, 3. Oslo, 4. Geneva, 5. Copenhagen, 6. Auckland, 7. Taipei, 8. Helsinki, 9. Bilbao, and 10. Dusseldorf. In the chart, Bratislava was ranked 84th among the assessed cities [18]. The term "Smart", i.e., intelligent, is used today to refer to such cities that make a real revolution in technologies that sell their intelligence to their residents.

The Smart City concept is the core of strategic city management, or municipality or region where modern technologies are used. At the same time, there is development and a connection between various activities and public services, thanks to which the city functions as e.g., transport, logistics, security, energy, building management, etc. [40]. The Smart City Index ranks cities according to the extent of innovative solutions.

In Slovakia, the Smart City index is applied, which monitors six areas, including economy, people, governance, mobility, environment, and housing. Each pillar consists of assessment facts, while the factors are recalculated by arithmetic mean. Alt3gether there are 31 relevant factors. The basis of the factor calculation is represented by 74 indicators, which are specific statistical data. The value of the factors is calculated from the indicators [42].

The Slovak Smart City Index monitors and compares municipalities in the so-called intelligent characteristics that are considered relevant. These characterize Smart City areas, which define the level of smart solutions in each municipality. If municipalities decide to proceed with the adoption and implementation of the Smart City concept, they must accept these characteristics in their development concepts and fully apply and implement them.

The main benefits of a Smart City include an increased level of city functionality, sustainability, an increase in the standard of living of citizens, a reduction in air pollution and an intelligent solution to traffic, an innovative economy, improved city infrastructure, and the digitization of public services:

(a) An increased degree of functionality of the city means that the city has achieved a functional economy, availability of employment, access to elementary aspects of prosperity, interconnectedness and connectivity of infrastructure, further reliable, sustainable, and low-cost sources of energy, accessibility to dignified forms of housing, adequate access to education and effective transportation.
(b) Sustainability: by this we understand the provision of access to citizens to the resources that are necessary for them regarding their preservation for future generations. This is a method that does not deplete resources or permanently destroy them. It is not only related to the environment, but also to the economy.
(c) The increase of the standard of living of citizens: a smart city offers its citizens a comfortable, healthy, safe, and active lifestyle. This includes aspects

affordable sources of energy, mobility, quality education, healthcare, efficient public services, environmental cleanliness, access to various entertainment and cultural opportunities, and a low crime rate.

(d) Reduction of air pollution and intelligent transport solutions are often motivated by environmental measures that encourage the use of public transport or bicycles. The result is less air pollution.

(e) Innovative economy brings three kinds of benefits. The first are the areas that help to strengthen the innovative and economic development of a city or region, such as innovative solutions in industry, community start-ups, and the support of more economically backward urban areas. The second area is the continuing vocational education and training of trained workforce, which will potentially attract new innovative business projects to the territory of the city or the region. The third aspect is the professional development of companies regarding high demands on the information and data they apply and use.

(f) Urban infrastructure requires the ability of the municipality to improve existing infrastructure and develop the new one. This is probably the most frequently analysed area, which includes transport, energy networks, the safety of public space and the quality of the environment, and recently also the ecological impacts and the purity of natural resources.

(g) The digitization of public services is a special aspect of urban infrastructure in which many cities often lag. Local self-governments include smart technologies to ensure better availability of administrative and public services to the population. This is, e.g., the possibility of electronic processing of mandatory administration within public administration [38].

Within the goals of the Smart City concept, investments play a crucial role, as they create permanent and long-term sustainable growth towards the urban environment, and towards companies involved in Smart City concept implementation. Investments bring in the most significant benefit to society—a combination of increasing know-how, education, innovation and economic profit of public budgets or the company's budget [38].

The document Guide to the intelligent development of cities and regions [28] defines 6 strategic domains through which the concept of smart cities and regions is most often applied. Their potential lies mainly in their mutual interconnection and continuity. The Intelligent Public Administration domain is a prerequisite for the cooperation of public, private, and civic organizations in the administration of public affairs and in the support of further development. Its main tools include innovative solutions to challenges, information and communication technologies, data-based decision-making and effective processes and services available in electronic form and through useful applications. The domain Intelligent life and services reflects the lifestyle and behaviour of citizens, the provision of a healthy and safe environment with a developed infrastructure, especially health, cultural, social, economic or sports.

The intelligent economy optimizes and supports new trade and business models, production with high added value, innovation support, creation of new products, services, and business models [7]. Smart city is a strategic concept that is applied at

two levels, primarily at the level of a strategic document that gives direction, goal and system to the development of a smart city; and at the level of development projects by which this concept is put into practice [2].

3.5 Starting Points of Economic and Social Development in the Regions

We can consider the UN Agenda for Sustainable Development 2030 (Agenda 2030) as a key international strategic document for creation and urban development, which contains a summary of the global commitments of the international community in response to the most serious challenges of today, such as climate change, poverty, increasing economic and social differences. the unsustainability of prevailing patterns of production and consumption, etc. These are problems that are very complex and interconnected. The Sustainable Development Agenda contains 17 goals in the field of sustainable development. The Slovak Republic signed up for the implementation of Agenda 2030 with the document Starting points for the implementation of Agenda 2030 for sustainable development, which was approved by Government Resolution no. 95/2016 [13, 14].

As part of the consultative process involving the government, municipalities and the professional public, the government resolution no. 273/2018 of June 13, 2018, approved the following six national priorities for the implementation of the 2030 Agenda:

(a) education for a dignified life,
(b) towards a knowledge-based and environmentally sustainable economy in the face of demographic changes and a changing global environment,
(c) poverty reduction and social inclusion,
(d) sustainable settlements, regions, and the country in the context of climate change,
(e) rule of law, democracy, and security, and
(f) good health, which consider the specificities of Slovakia and are the basis of further strategic and conceptual work.

These priorities also became the basis for formulating the vision and strategy for the development of Slovakia until 2030. These are reflected in the integrated development program document of the Slovakia 2030. They link the 2030 Agenda and regional development and represent a key tool for achieving the goals of the 2030 Agenda across the national, regional, and local levels, in the following structure:

1. Protection and sustainable development of natural and human resources, as well as cultural potential, so that they are preserved for future generations and can be used for further development of society.
2. Transformation of the Slovak economy by 2030 into a competitive, innovation-oriented, low-carbon circular economy that will effectively value education,

human potential and resources and will be environmentally and socially sustainable and resistant to external and internal adverse influences.
3. Streamlining and bringing the administration of public affairs closer to citizens through the construction of multi-level integrated development management at the national, regional, and local levels. At the same time, the goal is to effectively use the territorial potential of the regions.
4. Increasing the quality of life for all social groups in regional strategic planning documents and ensuring the availability and quality of public services, work, and equal opportunities in favour of the potential of everyone, regardless of the socioeconomic background or disadvantage.

At the national level, these global trends and policies are reflected in the important strategic document Vision and Strategy for the Development of Slovakia until 2030, which is the basic implementation document of Agenda 2030 for the Slovak Republic and represents the tasks of the National Strategy for Regional Development. This document is focused on several challenges and areas that bring about global changes, such as climate change, mobility, and migration, increasing globalization, the dynamics and instability of the world economy, the rapid development of artificial intelligence, the deepening differences between the rich and poor strata of the population, the rise of extremism and an increase in distrust of democratic institutions.

The document defines the following priorities for regional development:

(i) sustainable competitive, environmentally, and innovation-oriented economy in regions,
(ii) increasing the quality of life and the use of natural and human capital, and
(iii) harmonization of regional and territorial development.

It identifies problem areas and challenges, and defines targets expected to be achieved by until 2030. For example, it plans a 100% share of diverted and treated wastewater in agglomerations with more than 2,000 inhabitants and in all municipalities, a 35% share of public transport and at the same time shifting at least 20% of the load from road freight and passenger transport to rail transport, preference for rail transport and electro mobility, etc.

3.6 Self-government and Its Competences in the Development of SMART Regions

A region refers to a certain area or zone and is defined by a geographical space. A region is divided according to its common characteristics into a natural or geographical region, a cultural region, an economic or socio-economic region, a political or administrative region.

The tasks of self-government include:

(a) The coordination task relates to the processes of cooperation and coordination of activities with entities operating in its territory.
(b) The economic-management task relates to the economic-political nature of the territorial self-government.
(c) The allocation task relates to the allocation and placement of funds in the interests of residents.
(d) The redistribution task relates to the redistribution of resources in the interests of the community [1].

Regional self-government is part of the self-government of a higher territorial unit. By the Act of the National Council of the Slovak Republic no. 302/2001 Coll. on the Self-Government of Higher Territorial Units (Act on Self-Governing Regions) eight regional self-governments were established in Slovakia [31]:

1. Bratislava self-governing region.
2. Trnava self-governing region.
3. Trenčín self-governing region.
4. Nitra self-governing region.
5. Žilina self-governing region.
6. Banskobystrický self-governing region.
7. Košice self-governing region.
8. Prešov self-governing region (see Fig. 1).

To implement the plans in the effective management of municipalities, cities and regions, the SMART municipality should have a unified data base, which will be utilized to control public lighting in the territorial municipality, urban transport, water supply, freight transport, energy supply, waste management, parking, open city (WiFi). Citizens should have access to information platforms, charging stations for SMART devices, or smart bins, etc. At the same time, people's mobility, safety, and assistance will be controlled in the SMART municipality. Intelligent and

Fig. 1 Administrative division of Slovakia into self-governing regions

energy-economic buildings will be constructed, which will have fast internal logistics, economic use of energy, and economic thermal materials will be used during construction or reconstruction of buildings. Intelligent and economic mobility is related to citizens and goods, the transport of which should be comfortable, smooth, ecological, safe, and economic [49].

From the point of view of ecology, SMART self-government should ensure the reduction of energy consumption, waste, carbon footprint, light smog, etc. The way to this could be funds invested into the improvement of energy efficiency, the use of low-carbon energy, infrastructure modernization and operational responses to the detection of monitoring data with the aim of limiting or improving the current passability of roads, optimizing energy in public buildings, connecting public lighting and flexible deployment of means that dampen negative environmental conditions. Promising perspectives are expected from the application of nanotechnologies, such as nanocoatings with photocatalytic properties of buildings or other large areas in the municipality, which, under the action of light, decompose organic particles into water and carbon dioxide, a storehouse of data information.

Furthermore, there is a need for a virtual concept that would ensure a real-life view of SMART self-government, and an intelligent concept that introduces an element of creativity, innovation, human capital, the involvement of schools, organizations and citizens into the development of a smart city concept and its implementation, and a knowledge network requiring the support of vocational education and training, and qualified workforces at the time of creation of the Smart City and region.

The long-term goal of the Slovak Republic is the development of SMART regions from the following aspects:

(a) Quality of life as a superior level.
(b) Healthy life in a healthy community, that means a healthy, supportive, communicative, tolerant, unbiased, dynamic and inclusive society providing a welcoming social climate without any prejudice and bias.
(c) Feeling of safety—regarding the environment, performing physical activities in it, for example when walking, cycling and staying in company.
(d) Freedom of decision-making and movement—mobility and accessibility, also for residents with health disabilities and social limitations.
(e) Possibility of entrepreneurship of businesses and individuals.
(f) A place for education and knowledge sharing.
(g) Sufficient positive stimuli and motivation.
(h) Aesthetic quality of the environment.
(i) Suitable options for housing, leisure activities and work.
(j) Effective implementation of housing and leisure activities.

From the aspect of Smart environment, regions with the following characteristics were identified:

(a) A region with a low-carbon economy that minimizes the consumption of resources and volumes of waste through the prevention of waste production,

the system of payment for waste according to its production, the use of waste as a source of new materials.

(b) A region with a circular economy, which increases the emphasis on the reuse of land, materials, energy, and rainwater, with the prevention of waste production.
(c) Region increasing the use of modern technologies to provide effective services to the public.
(d) Region maximizing the use of modern technologies to effective use of all local resources.
(e) A region supporting the efficient use of resources through the introduction of modern technologies into urban life, SMART infrastructure.
(f) Region with SMART energy networks, green buildings, Internet of Things—energy sensors, electro-mobility, charging stations based on local energy sources and infrastructure.
(g) A region that preserves and effectively uses data systems for decision-making and control processes in both the public and private sectors while maintaining transparency and public control [28].

A smart economy in the regions can bring several incentives to the regions, due to which the regions specialize:

(a) A region that is a magnet for international talents, creating attractive incubation Smart communities.
(b) Region with an equal society.
(c) A region that uses its resources efficiently.
(d) A region that provides high-value job offers for efficient use of human resources.
(e) A region with flexible regulation that allows maximum use of internal and external potential, including foreign capital.
(f) A region with the production of goods and services with high added value and high quality, which reflects the needs of the inhabitants.
(g) An economy that understands and uses the cultural and creative aspects of the territory.
(h) Economy supporting the creation, distribution and dissemination of cultural activities, goods, and services.
(i) A region with an economy that supports the cooperation of people with different skills and competencies with the intention of supporting the creation and spread of innovations and erasing barriers between industries.
(j) A region integrating cultural and creative industry into its development plans.
(k) A region with a socially inclusive economy.
(l) A region providing a stable but flexible environment for the development of business activities.
(m) A region with a favourable tax environment for residents and entrepreneurs, which encourages optimal and efficient use of resources.
(n) A region with a thriving business culture; entrepreneurship culture as an important part of school education.
(o) Economy using local demands for goods and services.

(p) Economy respecting the current state and perspective of the availability of all resources and possible access to them.
(q) An environment supporting the incubation and development of startups as engines of innovative business. institutional capacities for its residents and other involved entities; reducing bureaucracy through the efficiency of territory management processes and high qualification of employees, including investments in their professional development.
(r) A region that effectively uses the potential of active involvement of the public and stakeholders in decision-making processes and other activities of the urban community, including the professional capacity of individuals and institutions in the city, e.g. humanitarian activities, mutual aid, public control, learning in the community, etc.
(s) Region supporting the development of human resources capacities through appropriate forms of education, skills development, information dissemination, involvement in decision-making processes and other ways.
(t) Region that enables residents to cooperate in research and development of products and services.
(u) A region that supports creative expression and provides the necessary infrastructure that enables the transition between creative skills and commerce/technologies, integrating cultural issues into development.
(v) A region that accepts provocative ideas and encourages people to look positively at the potential of their city/region.
(w) A region aware of the importance of its inhabitants, as they represent the main capital of the city; takes steps to attract people to the city and stabilize them.
(x) A region supporting accessibility and participation in cultural life as a basis for creativity support.
(y) Acceptance of creativity as a basic component of the region and its use in processes of change and development. A clear and attractive brand of the region, but also of local products and services.
(z) A region that builds a local creative industry and evaluates its local creative history, which is also the main goal of the Creative City project and the UNESCO Creative City candidacy.
(aa) Region increasing the use of modern technologies to provide effective services to the public [8, 28].

3.7 Regional Labour Market in the Development of SMART Regions

The digitization of SMART regions directly affects the labour market. Changes in the structure of employment, growth of employment, transformations within the economy will certainly show up during the development of the business cycle [49].

The onset of digitization will also change the labour market, for example, in an industrial enterprise, there will be a wider deployment of automation and robotization, and thus job vacancies, and a group of administrative workers and middle management, where automation systems may be deployed, may also be at risk.

Places in technical professions, especially developers and designers, can be considered stable, although it can be assumed that the demands for maintenance workers and repairmen will decrease.

A slight increase in jobs can be expected in the field of information technology. It will be expected that in the qualification structure all workers will master digital literacy. In public administration, a vulnerable group may be the officials whose routine work will be handled by automated administration systems.

Big changes are not expected in agriculture and forestry. There may be only minor savings for manual workers. It is possible that the released workers will find work in services and telecommunications, or in the IT sector.

In Slovakia, the sectors with the highest share of high-risk employment include several sectors of the processing industry, wholesale and retail, services with a small number of employees, activities of gambling and betting offices, legal and accounting activities, security and search activities, activities of restaurants, cashiers, salespeople, business representatives and workers in warehouses. From the branches of the processing industry, it is mainly the production of motor vehicles, semi-trailers and trailers, which will need qualified assembly workers. Of the other industries, it is mainly the production of machines and equipment, the production of metal structures and metal processing [22, 25].

Technologies incite new jobs, mainly in the field of development, maintenance, and modernization, including artificial intelligence and data and infrastructures. However, it is difficult to estimate in advance how many such jobs will be created during the construction of SMART regions.

Nevertheless, it can be assumed, according to EU countries, that the newly created jobs will require higher level of education, intensive use of social and interpretation skills and at least basic knowledge of information and communication technologies. Furthermore, it could be noted that the main obstacle to the automation of work is the human-cantered organization of work. Aspects of work that require key attributes of human work, such as creativity, independence, and sociability, go beyond the current capabilities of advanced automation.

However, if the work is organized in a very addressable, standardized, and predictable way, it can be automated. Therefore, any change in the structure of jobs because of new technologies will require adaptation, change and modification of work tasks, and thus also the necessary skills and knowledge of the worker. The Slovak Academic Association for International Cooperation [37] notes a lack of digital skills in Slovakia. At present, up to one third of the EU workforce has no or very limited digital skills. EU employers report that large numbers of workers are currently unprepared to meet the growing demand for digital skills.

The vision and strategy for the development of Slovakia until 2030 touches on the development of human resources in areas that are directly related to the recommendations for adult education, for example:

(a) connecting the profiles of university workplaces in the regions to the labour market requirements and to the demands of the regional economy,
(b) introduction of a system for verification of qualifications, which will enable the recognition of the results of non-formal and lifelong education,
(c) creation of conditions for increasing the media literacy of a wide range of recipients of information disseminated by various, especially digital platforms through formal as well as lifelong education.

The OECD also commented on adult education in Slovakia in the document OECD Skills Strategy for the Slovak Republic; Assessment and recommendations [22, 33].

To support greater adult participation in education, the OECD recommends:

(a) coordinated implementation of the adult education policy at all levels, supported by updating the lifelong learning strategy and improving coordination between ministries and key players.
(b) increasing the participation of adults in education off the job.
(c) involvement of businesses and companies in adult education. Regions play an important role in adult education and should participate in the development and implementation of a modern adult education strategy together with all key stakeholders.

Under the influence of recommendations and based on several strategic documents, legal acts on lifelong learning, adult education, further education, and other relevant acts were adopted [5, 47].

4 Implementation of the Smart City Concepts in the Regions of the Slovak Republic

The Slovak cities were included in the Smart City Index rating for the first time in 2017. This has confirmed the fact that the smart city concept arrived in Slovakia with a significant delay compared to other European cities.

Bratislava was included in the pool of a little over a hundred assessed cities. Bratislava´s position improved in the following year, but it still lags in many areas. Other Slovak cities are just catching up and none of them has been included in the global assessment through the Smart City Index. There is a visible trend that several other cities in the Slovak Republic are trying to catch up. Unfortunately, Slovakia lags in this indicator, and that is because Košice, the second largest city in Slovakia, is still significantly behind. However, it is not the phenomenon of the larger size of the city that would predetermine a greater degree of implementation of the Smart city concept. It often happens that it is precisely smaller cities that develop a better approach to the Smart city concept than some cities with a larger area and a larger number of inhabitants.

Slovak Business Agency presents the level of implementation of smart city concepts in some Slovak cities (SBA 2021) through the Smart City Index. This

index assessed Slovak cities in six categories such as economy, people, governance, mobility, environment, and housing. The index provides entrepreneurs who are dedicated to innovation a comprehensive view of businesses with higher potential and identifies an opportunity to focus on long-term sustainable development. The ranking pointed to the persistent difference in the approach of Slovak regions to the implementation of Smart city concepts. In the parameters monitored by the Slovak Smart City Index, West Slovak cities are in the leading positions. As a positive factor, we can include the fact that the index showed a positive trend in smart solutions implemented in the lives of residents living in tourist areas in the north of Slovakia [38].

Even though several state institutions, regions, cities, and municipalities deal and include the Smart city concept in their documents and strategies, there is still no comprehensive unified strategy that serves as a manual or guide on how to create Smart city concept. Intelligent cities are most often included in the planning of Slovak cities and municipalities in some elements of the energy, environment, education, and communication strategy. In more developed forms, the concept is also part of spatial planning or digitization schemes [38].

Rarely is the Smart City concept utilized in the plans and projects within the health and social infrastructure. More often, it is possible to see the implementation of smart solutions in social community projects, where the initiative of cities and municipalities is often replaced by the activities of non-profit organizations.

4.1 Implementation of the Concept of Smart City in the Prešov Region

The Slovak Republic is a unitary state in Central Europe, which at present consists of 8 regions and 79 districts. Regions are the main administrative units in the Slovak Republic and are responsible for the coordination and management of regional affairs. Districts are smaller administrative units that serve to manage and coordinate affairs at the district level.

The regional aspect of Smart City concept focuses on the use of smart technologies and innovative solutions to support sustainable development and improve the quality of life of residents within a specific territory or a region. One of the key areas on which the regional aspect of the Smart City will focus is the development of transport and mobility. This can include the use of intelligent transport systems to improve traffic flow, reduce impermeability and emissions, and to support alternative modes of transport such as cycling and walking.

In addition, the regional aspect of the Smart City concept seeks to improve environmental quality and sustainability. This applies, for example, to the waste management, energy management, and water management. Smart solutions can help minimize the impact on the environment and improve its protection. In the regional Smart City context, it is important to work with authorities and residents at district, city and

municipal level to achieve common goals and ensure that smart solutions are truly beneficial for the entire territory of the region and its residents.

The Prešov region is in the north-east of Slovakia. It is the second largest region in Slovakia and has an area of 8,973 km^2. The region is rich in cultural and historical traditions. Most of the territory is mountainous, which is considered a disadvantage in terms of national and international transport and communication links [36].

The number of inhabitants as of 31.12.2021 was 807,657 people. There is a lack of job opportunities in the Prešov region, so jobseekers depart to other Slovak regions or abroad to find work. The unemployment rate in the Prešov region has long been among the highest and reached 11.4%. The average salary in 2021 was €1,157 and was among the lowest in Slovakia. In 2021, there were 28,800 legal entities operating in the Prešov region, a third of which were engaged in construction and in technically oriented trades. There were 60.2 thousand self-employed persons and most of them were engaged in construction, industrial production, and trade. Regarding the GDP, the Prešov region is one of the less efficient regions. The gross domestic product in 2021 reached a value of 8,985 million euros in current prices.

There are many school facilities in the Prešov region. In 2021, 63 secondary vocational schools, 38 gymnasiums (general secondary schools), 390 primary schools and 546 kindergartens were registered [46]. The Prešov region has the longest northern border with Poland, in the east with Ukraine, in the south it borders with the Košice region and the Banská Bystrica region, and in the west, it is adjacent to the Žilina region. The Prešov region includes 665 municipalities, 23 of which have been granted city status. The regional capital of the Prešov Region is Prešov. The Prešov Region is administratively divided into 13 districts (Fig. 2) including Humenné, Poprad, Stropkov, Prešov, Medzilaborce, Kežmarok, Svidník, Levoča, Vranov nad Topľou, Snina, Sabinov, Bardejov and Stará Ľubovňa [36].

Fig. 2 Administrative districts in the Prešov region. *Source* po-kraj.sk

Table 3 presents the current projects in transport, environment, and open self-government, which the Prešov Region deals with. Subsidies are obtained from EU sources, and they help in various areas of urban development. The Prešov region is included among the regions that deal and work within the Smart City concept.

The development pillars of Kežmarok municipality represent the basis for the improvement of the quality of life and economic growth. The pillars do vary in different cases, but they usually cover three categories, including economic development, social security, and environmental protection [29].

Kežmarok ranks among the first municipalities in Slovakia that started to implement the Smart City concept on its territory. The municipality self-government is trying to achieve a status of Smart City, i.e., to achieve the level of an intelligent city that uses modern technologies to improve the quality of life of its residents. One of the initiatives implemented by Kežmarok municipality is the creation of a unified information system, which would enable efficient management of the municipality infrastructure, improvement of public transport and provision of high-quality service for residents.

The self-governing body in Kežmarok has been working to improve its environmental profile. Of the large number of activities in the field of green and waste management, there is an increase residents' awareness, especially about waste separation, and biodegradable waste, which is composted, and wood chips, which are used for mulching flower beds.

Forestry education days are organized annually, focusing on green infrastructure, nature, and landscape protection. The municipality of Kežmarok is currently investing mainly in public lighting and construction of Smart buildings, and at the

Table 3 Three pillars of the development of the Prešov region

Pillar	Strategic activity
Transportation	Masterplan—a strategy for the sustainable development of transport Public transport—purchase of new trolleybuses Modernization of existing and construction of new trolleybus lines, also reconstruction of the depot Creation of cycle paths and related infrastructure Modernization of transport hubs Reconstruction and modernization and construction of parking lots Purchase and installation of intelligent parking systems
Environment	Development of the SECAP document Reduction of energy consumption in public buildings Newly planned energy saving projects Modernization of public lighting Waste management program Restoration of public spaces and inner blocks
Open self-government	E-government

Source Prešov je smart [35]

same time monitors energy spending and energy parameters of buildings. The municipality is currently implementing a project of a solar power plant construction and a project of the improvement of the energy efficiency of public buildings.

In addition, Kežmarok municipality strives to improve its cultural and tourist attractiveness for residents and visitors. There are many historical monuments and attractions, which need to be effectively managed and made visible. A project for the digitalization of cultural heritage is implemented and would enable a better presentation of cultural attractions. Kežmarok municipality has ambitious plans and is actively working to become a modern and intelligent city that can provide quality services for residents and an attractive environment for visitors.

The municipality is currently adjusting the development strategies, giving priority to housing with low energy consumption, supporting the modification of the environment, limiting the expansion beyond its borders and supporting the combination of housing and shops and services, density of population, and micromobility.

The municipality of Kežmarok has developed a development strategy focused on four areas including waste management, environment and greenery, reduction of air pollution, adaptation, and mitigation of waste to climate change. Kežmarok focused on the three main pillars of the development (Table 4), the main tasks include mainly the increase of employment opportunities. These three pillars represent key factors in the development of Kežmarok. The municipality administration strives to achieve concrete results and create opportunities for residents in each of these areas (see Tables 5 and 6).

Projects to increase energy efficiency and the reconstruction of the public building, social and sports centre, the reconstruction of the town hall, the completion and complete equipment of the winter stadium, the energy audit of the buildings, the renovation of the city market, the introduction of new smart technologies valued 1 million euros and water retention measures valued1 million euros are in the process of implementation.

Figure 3 presents partnerships supporting the development of the Smart City concept in Kežmarok. Key partners are the Digital Coalition, the European Group of Territorial Cooperation, the Slovak Smart City Cluster, the Covenant of Mayors

Table 4 Three pillars of the development in Kežmarok

Pillars	Strategic activity
Environmental balance	To ensure a decent quality of life for residents, visitors and tourists. The main task is to attract as many young people and investors as possible to place their investments in Kežmarok
Economic balance	Bring a new economic impetus to the development of the municipality, increase employment and create new job opportunities
Social balance	Fulfil the needs of target groups, including residents, tourists, visitors, entrepreneurs and business entities

Source Own processing in accordance with the Program of economic and social development of Kežmarok for 2014–2020 [19]

Table 5 Vision of development in Kežmarok until 2025

Year	Implementation
2017	A concept of the Smart City was developed that fulfilled the Smart City vision and defined its priorities
2018	An Action plan was created—a strategy with measurable indicators for the implementation of projects
2022	Introduction and assessment of Smart City projects in Kežmarok included the assessment of specialist and the opinion of the public
2025	Kežmarok has declared the ambition to rank among the best Smart Cities in Slovakia

Source Own processing due to [9]

Table 6 Projects in Kežmarok in 2020–2021

Project	Value in euros (€)
Recovery of biodegradable waste	2,8 million €
Center of integrated health care in Kežmarok	5 million €
Complete reconstruction of the national cultural monument Reduta	0,42 million €
Completion of basic technical infrastructure in Kežmarok	0,84 million €
Reconstruction of the Renaissance national cultural monument Zvonica	0,5 million €
Restoration of the fire station	0,040 million €

Source Own processing due [9]

for Climate and Energy Europe, the Association of Cities and Towns of Slovakia, Urbact Driving change for better cities, Euroregion and the Union of Slovak Cities.

The municipality of Kežmarok focuses on several areas of interest that are considered important for the development of the town [30], e.g.:

1. Culture and tourism: Kežmarok has a rich history and many cultural attractions that need to be made visible and managed effectively. In this area, the municipality tries to improve the quality of tourist services and create new opportunities for the development of tourism.
2. Infrastructure and technologies: Kežmarok tries to use modern technologies to improve the quality of life of residents and to manage the town efficiently. In this area, it focuses on the improvement of public transport, the management of urban infrastructure, the creation of a unified city information system and the improvement of the energy parameters of public buildings.
3. Business and economy: the municipality tries to create opportunities for business development and improve the economic growth of the city. In this area, it supports small and medium-sized enterprises, jobs creation, tourism development and tries to attract investments.
4. Social issues: Kežmarok municipality tries to improve the quality of life of residents. In this area, it supports socially weaker groups of residents, promotes

Fig. 3 Partnerships of Kežmarok municipality. *Source* Modernization of local territorial self-government [30]

the development of social services, the improvement of living conditions and provides family support.

5. Environment: Kežmarok municipality tries to protect and improve the quality of environment. In this area, it promotes effective waste management, improvement of air quality, protection of natural resources and green areas.

These areas are extremely important for the municipality of Kežmarok, and the self-governing body tries to achieve specific results in each of them. The smart city concept is intended to bring to Kežmarok the most efficient expediency and improve the quality of life of residents. This includes the launch of optical Internet and the construction of an Internet network [34], where all organizations belonging to the self-government should be connected, partial replacement of public lighting, establishment of energy management and a unified economic system. Deficiencies are to be eliminated especially in energy and transport [20].

The concept of Smart City is focused on the utilization of financial resources of the municipality, the state budget, and the funds of the European Union. Currently, Kežmarok managed to involve employees from several companies, the public and the municipality officials in the beautification of the town by planting trees and permanent flower beds. To protect the air, the municipality supported non-motorized transport by building a bicycle path that leads through the historic Centre, and supported low emission means of transport (electromobility).

The overall improvement of the environment positively affects the health of residents. This is the vision of the concept, according to which the dynamic, modern and historical Kežmarok is being built (see Table 7).

An important area is the improvement of the municipality transport and green mobility. For this area, Kežmarok municipality has adopted a concept implemented

Table 7 Vision of transport and green mobility until 2025

Year	Vision and implementation
2014–2019	Traffic lights, roundabouts, responding to increased traffic in Kežmarok
2015	Automatic parking system with ramps and payment machines
2014–2019	Construction of cycle paths, support of cycle tourism and reconstruction of footpaths
2019	Support for electromobility, construction of a charging station, purchase of an electric car
2020	Low-carbon urban public transport, integrated public transport, smart parking + smart traffic management
2025	PRIORITY—Green transport

Source Reference [9]

from 2014 to 2025. The situation in transport is constantly improving and coming closer to its goal annually. Table 7 shows the vision and implementation in transport and green mobility that the municipality wants to achieve by 2025, including the transition to green transport, which has become a priority.

The funding of projects in Kežmarok is presented in Table 8. For the year 2023, the municipality of Kežmarok approved a budget in the amount of €27,062,516 for project financing in March 2023. Multi-source financing and financial support from several programs were utilized:

Table 8 Funding of projects in Kežmarok

Funding	Programs
Bilateral funds	Pilot scheme for supporting development and innovation projects, especially for smart cities in the Slovak Republic (Norwegian financial mechanism)
European structural and investment funds	Integrated regional operational program Rural Development Program Operational program Environment Operational program Human resources Research and innovation operational program
Cooperation with international financial institutions	Tools of the Slovak state budget, EIB to support Smart City projects
Financial instruments processed by the European Commission	Horizont 2020 COSME URBACT
Programs of cross-border, transnational and interregional cooperation	Interreg Central Europe 2020 URBACT III

Source Own processing due to [9, 16]

(a) The pilot scheme for development and innovation projects, especially for building smart cities in the Slovak Republic, is financed through the Norwegian financial mechanism. The aim of the pilot scheme is to support projects aimed at development and innovation in the smart cities in the Slovak Republic. Grants are intended for Slovak local governments (municipalities), civic associations, universities, and businesses. The goal of the scheme is to support projects that contribute to sustainable development and increase the quality of life of residents in all regions of Slovakia.
(b) The Integrated Regional Operational Program (IROP) was utilized in Kežmarok to finance projects in areas such as improving transport connections, restoring cultural heritage, supporting business and employment, building energy-efficient buildings and facilities.
(c) The Rural Development Program (RDP) focuses on the development of rural areas, including the support of agriculture, forestry, and the development of rural towns.
(d) The Operational program Environment supports projects that improve the quality of the environment and nature protection, including wastewater treatment plants, waste separation and disposal, and increasing the energy efficiency of buildings.
(e) The Operational program Human resources is used to support education, employment, and social inclusion.
(f) The research and innovation operational program provide funding for research and innovation in various areas, such as the automotive industry, information technology and healthcare.

Additional funds will be available from other sources in the case of relevant projects, such as:

(g) The European Investment Bank (EIB) provides financing for various Smart City projects, such as the construction of energy-efficient buildings, the development of public transport and parking, the development of intelligent public lighting management, the use of renewable energy sources, the improvement of waste management and the increase of environmental quality of Smart city.
(h) The tools of the Slovak state budget focus on the financing of projects in the field of energy, transport, environmental protection, and social infrastructure. These instruments are usually provided as co-financing of those projects, a large part of which is financed by the financial instruments of the European Union.
(i) Horizon 2020, COSME and URBACT are programs and initiatives of the European Union that support innovation, competitiveness and sustainable development of cities and regions. In Kežmarok, it is possible to use these programs to finance projects in the field of research and innovation, business support and local infrastructure development. Specifically, within the Horizon 2020 program, funds could be obtained to support research and innovation in areas such as energy, transport, Smart City and sustainable environment. In turn,

COSME could provide financial support for small and medium-sized enterprises in Kežmarok, while URBACT could be used to improve local planning and self-governing management.

(j) Interreg, Central Europe 2020 and URBACT III are European programs supporting cooperation between regions and municipalities and cities in areas such as innovation, sustainable development, culture, social affairs, and others. In Kežmarok, these programs can be used to finance projects that contribute to the development of the Smart city and Smart region concepts, for example, to improve the quality of public spaces, to promote the creative industry, tourism and more.

5 Discussion

The content of the study focused on several theoretical and practical aspects of the creation and development of smart cities concept in the context of regional development policy. These were aspects that are tangible and economically quantifiable. In the study, we partly paid attention to the issue of human resources development, as it is undoubtedly related to the mentioned issue. In the context of endogenous theories of regional development, human resources are irreplaceable. The authors examined this issue as a separate topic and found out that it is extremely complex and wide-ranging [22, 23, 26]. Innovations are directly related to human resources, their professional education and training, further professional education and retraining during the productive phase of life of workers. The results of other studies (e.g., OECD [33]) point to the urgent need to start addressing the issue of vocational training and education within lifelong learning in Slovakia and to focus further training and further vocational education on the challenges of the circular economy. From this aspect, we agree with Kislingerová et al. [21] who specified the circular economy as a new social paradigm that reflects "broad social agreement on prioritizing those parameters of the economic environment that should lead to qualitatively new production cycles in terms of the efficiency of the use of raw materials" [21]. An equally important aspect is the issue of effective management of natural resources in business activities and the creation and development of smart regions. In connection with this, Nováček [32] states that "current trends include the green economy, green investments, and sustainable development. The business environment must respect Slovakian and European trends and adapt to new challenges and harmonize its economic activity with valid legislation" [32]. A worrying trend associated with the development of the globalization of the world economy is the fact that natural resources are diminishing, and economic goals exceed ecological goals. The author pointed out that "the Prešov region is relatively rich in sources of natural mineral healing waters and deposits of ore raw materials. There are natural sources of mineral waters such as Cigeľka, Salvator, and Baldovská" [32]. All mentioned aspects of economic activity relate to business activities, as well as with the development of regions and the development of smart cities and smart regions concepts. They cannot be left out in the concepts

of smart cities and their implementation. Finally, all of them are currently part of the innovation index that is applied in the Slovak Republic.

6 Conclusion

We emphasize that it is mainly innovations that contribute to the development of municipalities, cities and regions and benefit residents in the form of sustainable solutions. Innovative ideas also find application in the management of public affairs. Their purpose is primarily to improve the quality of life of residents and visitors of respective territories. Technological innovations such as innovative technologies, artificial intelligence, the Internet, analytical data processing, and blockchain are the basis of the digital transformation of society at large. Digital transformation affects citizens, entrepreneurs, economic entities, and public sector entities with an impact on the economic, environmental, and social growth of the country and its regions with an emphasis on sustainable development. When supporting innovation, Slovakia needs to focus on supporting key areas, including data collection and data policy, sufficient funding, predictable regulations, and the management of retaining and attracting talent in various positions. It is important that all sectors cooperate in Slovakia and other EU member states, including the government and the self-government, the private sector, the academic community, and the public. From the aspect of the real application of the concept of smart cities in Slovakia, the example of Kežmarok can be a suitable inspiration for how to involve the municipality, residents, entrepreneurs, and other economic entities in building a smart city, which will have an impact on the development of the district and the surrounding area.

References

1. Adamcová, M.: Teória verejnej správy. Košice: Univerzita Pavla Jozefa Šafárika v Košiciach. ISBN 9788081525872. s. 70 (2018)
2. Andrejčák, J.: Smart riešenia v doprave z pohľadu mesta Košice a mestských častí, ich uplatňovanie v praxi. In: Trvaloudržateľný rozvoj v krajinách Európskej únie II. p. 6 (2020)
3. Bratislava rozumné mesto 2030. Koncepcia Smart city (2018). https://zastupitelstvo.bratislava.sk/data/att/23774.pdf
4. Chauhan, D., Sharma, S., Singh, V.: Roadmap from 4G to 6G in smart cities impact and challenges. Int. J. Wirel. Microw. Technol. (IJWMT) **13**(6), 39–50 (2023). https://doi.org/10.5815/ijwmt.2023.06.05
5. Cigánová, K., et al.: Odporúčania pre verejnú politiku vzdelávania dospelých na Slovensku. s. 9 (2020)
6. Digi.City: Definitions, Digi.City (2020). https://www.digi.city/smart-city-definitions
7. European Innovation Scoreboard (2022). https://research-and-innovation.ec.europa.eu/statistics/performance-indicators/european-innovation-scoreboard_en
8. European Innovation Partnership on Smart Cities and Communities (2011). https://e3p.jrc.ec.europa.eu/articles/european-innovation-partnership-smart-cities-and-communities
9. Ferenčák, J.: Smart Green City Kežmarok (2019)

10. Finka, M., et al.: Sprievodca inteligentným rozvojom miest a regiónov (2022)
11. Funta, R.: Relationships between platforms and retailers (on the Example of Amazon). AUC Iuridica **69**(2), 83–94 (2023). https://doi.org/10.14712/23366478.2023.16
12. Gajdoš, P.: Ako sa mení vidiek na Slovensku (2015)
13. Government of the Slovak Republic: Resolution no. 95/2016 Starting points for the implementation of the 2030 Agenda for sustainable development (2016)
14. Government of the Slovak Republic: Resolution no. 273/2018 of June 13, 2018 Implementation of the 2030 Agenda (2018)
15. Gregušová, D., Halásová, Z.: EIDAS regulation and its impact on national legislation: the case of the Slovak Republic. Adm. Sci. **12**(4), 187 (2022). https://doi.org/10.3390/admsci12040187
16. Habánik, J.: Klastre a inovácie v prostredí regionálnej ekonomiky. In: Sociálno-ekonomická revue, p. 15 (2012). ISSN: 1336-3727
17. Hučková, M., et al.: Podpora inovatívnych riešení v slovenských mestách. s. 18 (2017)
18. IMD Smart City Index. https://www.smartcity.gov.sk/projekty-v-zahranici/imd-smart-city-index/index.html
19. Kežmarok:2023: Program hospodárskeho a sociálneho rozvoja mesta Kežmarok 2014–2020
20. Kežmarok:2023. Smart Green City Kežmarok. https://www.kezmarok.sk/aktuality/kategorie-aktualit/smart-green-city-kezmarok/
21. Kislingerová, E., et al.: Cirkulární ekonomie a ekonomika. Spoločenské paradigma, postavení, budoucnosti a praktické souvislosti. Praha: Grada Publishing, a. s. 2021, ISBN 978-80-271-3230-0. s. 256 (2021)
22. Kollár, V., Matúšová, S.: Competitiveness in the context of human potential in the Slovak Republic. In: Economy & Business. Journal of International Scientific Publications, vol. 16 (2022). www.scientific-publications.net
23. Kollár, V., Matúšová, S.: Human resources development in the solution of regional disparities in Slovakia. In: 8th International Scientific Conference ERAZ 2022—Conference Proceedings (2022). https://doi.org/10.31410/ERAZ.2022.211
24. Kollár, V., Palková, G.: Inovačná výkonnosť Slovenska a jeho regiónov. Verejná správa a regionálny rozvoj **18**(1), 14–31 (2022)
25. Luptáčik, M., et al.: Hospodárske a sociálne dopady priemyslu 4.0. 119 s. (2021)
26. Matúšová, S., Kollár, V.: Výzvy cirkulárnej ekonomiky na trhy vzdelávania a trhy práce. In: Challenges, Trends and Inspirations within the Labour Market. Trenčín: Trenčianska univerzita Alexandra Dubčeka, pp. 166–174 (2022)
27. Ministry of Economy of the Slovak Republic: Podpora inovatívnych riešení v slovenských mestách. s. 85 (2022)
28. Ministry of Investments, Regional Development and Informatization of the Slovak Republic: Smart City. Benefity Smart Cities (2023). https://mirri.gov.sk/aktuality/cko/tema-smart-city-je-jednou-z-priorit-slovenska-pre-nove-programove-obdobie/
29. Mohammadinejad, H., Mohammadhoseini, F.: Privacy protection in smart cities by a personal data management protocol in blockchain. Int. J. Comput. Netw. Inf. Secur. (IJCNIS) **12**(3), 44–52 (2020). https://doi.org/10.5815/ijcnis.2020.03.05
30. Národný projekt Modernizácia miestnej územnej samosprávy. Inovatívne riešenia chránia majetok a zdravie (2021)
31. National Council of the Slovak Republic: Law no. 302/2001 Coll. on self-government of higher territorial units (Act on self-governing regions) (2001)
32. Nováček, P.: Využívanie nerastných zdrojov v rámci podnikania na Slovensku. Verejná správaa regionálny rozvoj **18**(1), 129–140
33. OECD: Stratégia zručností pre Slovenskú republiku (2021)
34. Prasanna, K.G., Shankaraiah, N.: An efficient IoT-based ubiquitous networking service for smart cities using machine learning based regression algorithm. Int. J. Inf. Technol. Comput. Sci. (IJITCS) **15**(3), 15–25 (2023). https://doi.org/10.5815/ijitcs.2023.03.02
35. Prešovský samosprávny kraj: Prešov je smart (2023). https://www.presov.sk/presov-je-smart-oznam/mid/311356/.html
36. Prešovský samosprávny kraj (2023). https://www.po-kraj.sk/sk/fakty/zakladne-informacie/

37. SAAIC: Zmena charakteru práce a zručností v digitálnom veku (2020). https://www.eurogu idance.sk/index.php?sw=9
38. Slovak Business Agency: Koncept Smart Cities a jeho vplyv na malé a stredné podniky (2021)
39. SIEA: Ukazovatele výkonnosti výskumu a inovácií v SR. 2023 (2019).
40. Slavík, J.: Smart City v praxi. Jak pomocí moderních technologií vytvářet město příjemné k životu a přátelské k podnikání, p. 12 (2017)
41. Smart City Centre: Smart City Features (2017)
42. Smartcity: Index inovácie slovenských samospráv (2023). https://www.smartcity.gov.sk/projekty-na-slovensku/index-inovacie-slovenskych-samosprav/index.html
43. Stratégia Európa 2020. https://eur-lex.europa.eu/legal-content/SK/TXT/?uri=celex%3A52010DC2020
44. Svítek, M., et al.: Města budoucnosti, p. 168 (2018)
45. Srebalová, M., Peráček, T.: Effective public administration as a tool for building smart cities: the experience of the Slovak Republic. Laws **11**(5), 67 (2022). https://doi.org/10.3390/laws11050067
46. Statistical Office of the Slovak Republic (2023). https://slovak.statistics.sk/wps/portal/ext/themes/regional/presovsky
47. Štefániková, Z.: Sieť nezávislých národných expertov v oblasti vzdelávania dospelých/zručností dospelých, p. 14 (2018)
48. Territorial Agenda of the European Union: 2020. https://ec.europa.eu/regional_policy/sources/policy/what/territorial-cohesion/territorial_agenda_2020.pdf
49. Veber, J., et al.: Digitalizace ekonomiky a společnosti, pp. 166–170. Management Press (2018). ISBN: 9788072615544

The Relationship of Sustainable Project Management to Project Success—A Current Literature Review

Kilian Weih and Michal Greguš

Abstract This research paper employs a structured literature review to investigate current publications that examine the relationship between sustainable project management and project success. Based on seven recent publications since 2020, the study addresses the research question of what influence sustainable project management has on project success.

Keywords Sustainable project management · Project success · Literature review · Comenius University · Sustainability · Project management standards

1 Introduction

In today's world, it is critical to integrate sustainability into the strategies and practices of businesses and organizations. More and more companies are recognizing that they have social and environmental responsibilities and that their decisions can impact the well-being of people and the planet. As a result, companies are seeing sustainability as an integral part of their business strategy [1] and are beginning to focus on ways to improve their business practices to make them more sustainable [2, 3].

Due to its magnitude and impact, sustainability is also referred to as one of the twelve megatrends and is therefore a driver of change [4]. As a result, project management had to engage with the topic of sustainability. It has since become one of the most important global trends in project management [5], as evidenced by a growing number of research and publications on this topic [6–8]. Despite growing research and literature on sustainable project management, there is still a need for further exploration of the relationship between sustainable project management and project success. To ensure a thorough investigation of the relationship between sustainable

K. Weih · M. Greguš (✉)
Comenius University in Bratislava, Odbojárov 10, 82005 Bratislava 25 Bratislava, Slovakia
e-mail: michal.gregus@fm.uniba.sk

K. Weih
e-mail: weih1@uniba.sk

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2024

P. Štarchoň et al. (eds.), *Data-Centric Business and Applications*, Lecture Notes on Data Engineering and Communications Technologies 213,
https://doi.org/10.1007/978-3-031-62213-7_17

project management and project success, this study first provides a comprehensive review of the concepts of "project management", "sustainability", and "sustainability in project management". Following this, a structured literature review is conducted, which examines the most recent publications that have investigated the relationship between sustainable project management and project success. Based on these findings, the study aims to determine whether sustainable project management has a positive impact on project success.

2 Theoretical and Conceptual Background

2.1 Project Management

It is not possible to attribute the invention of the term "project management" to a single individual, as it was developed over a period of time and emerged from practical experience, drawing from various disciplines. The definitions and concepts of project management have evolved and become more refined over time.

To gain a deeper understanding of the term project management, a closer look at the word "project" is necessary. According to the German industry standard no 69901, a project is defined as an undertaking that is essentially characterized by the uniqueness of its conditions, such as target specifications, temporal, financial or other limitations, demarcations from other projects and a project-specific organization. In addition, other project characteristics can be found in the literature, such as novelty, risk, complexity, involvement of multiple parties or uncertainty [9, 10]. In addition to its temporary nature, a project has both a beginning and an end. It can exist independently or be part of a larger program or portfolio [11].

The interconnection between the concepts of project and management inevitably raises the question of what is specifically encompassed by these terms. The Project Management Institute states that project management involves the effective use of skills, knowledge, methods, and tools to successfully meet the requirements of a project. It focuses on directing project work to ensure that the desired outcome is achieved. Project teams have the opportunity to achieve their goals through various approaches, such as plan-driven, hybrid, or adaptive methodologies [11]. According to Holzbaur, it includes all management tasks, organization, technology and resources for the operational implementation, monitoring and support of projects [12].

There are three significant standards for project management according to a study by Kostalova and McGratz. The standard of the Project Management Institute in the form of a guide for project management [11]. The second important standard is Projects IN Controlled Environments2 (PRINCE2), managed by the Association for Project Management Group Ltd. [13]. The third standard is the IPMA Competence Baseline Standard of the International Project Management Association, which is adapted in national competency-based standards [14]. All standards provide a

methodology of project management [15], associations initiate research and development of their standards, education of project managers and certification of their knowledge [16].

A study commissioned by the German Society for Project Management (GPM) on the "projectification" of society analyzed key factors influencing this trend. According to the study, the greatest trend is digitalization, followed by sustainability and climate change [17]. Therefore, the project management of the future must deal with the change of society, future trends and especially sustainability.

2.2 Sustainability

The concept of sustainability has its origins in forestry. As early as 1713, Carl von Carlowitz called for a sustainable and permanent use of forests. Cut down trees must be replanted to ensure that the resource base is not depleted. He spoke of the wise management of forests in this context [18]. The World Commission on Environment and Development defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [19]. In the further course, the triple-bottom line (TBL) theory has established itself as a concept that encompasses the environmental, economic and social aspects.

The theory states that the three dimensions influence each other and cannot be developed independently. The economic dimension deals with financial aspects, the ecological dimension deals with the management and protection of natural resources, and the social dimension deals with the maintenance of social capital and solidarity. Sustainability therefore means balancing social, environmental and economic interests. Although there are over 100 definitions of sustainability, there is widespread agreement that the broader triple bottom line theory of sustainability must simultaneously balance [6, 20]. The urgency of taking sustainability into account in today's society is shown by the Global Risk Report published annually by the World Economic Forum. Here, ecological risks have already been reported among the top 5 global risks since 2011 [21]. Environmental risks also play a prominent role in the Global Risk Report 2023. 5 of the 10 short-term risks and 6 of the 10 long-term risks address environmental risks, with environmental risks alone occupying positions 1 to 4 [22].

2.3 Sustainability in Project Managment

A large number of different definitions of sustainable project management can be found in the literature. This makes it particularly clear from which different disciplines and different focal points the variables sustainability and project management can be approached. In a study by Zakrzewska [8] definitions of sustainable

project management have already been compiled. During the author's research, further definitions were identified in the literature, which are summarized below (Table 1):

Sustainable project management thus refers to the planning, monitoring and control of project delivery and support processes, taking into account the environmental, economic and social aspects of the life cycle of the project's resources, processes, outcomes and impacts, with the aim of realizing benefits for stakeholders. This is done in a transparent, equitable, and ethical manner that incorporates proactive stakeholder participation [2]. In this context, Holzbaur and Fierke state that in order to bring sustainability into project management, a cultural change must take place within the companies themselves. Sustainable goals can only be achieved by breaking down this topic to the respective projects and in this respect requires the support of the executives. In the course of integrating sustainability within companies, the literature refers to sustainability principles, although there is no consensus in defining these principles [27]. Thus, the sustainability principles identified by [23] were further substantiated by Holzbaur and Fierke (Table 2):

The multitude of different definitions in connection with the increasing number of scientific publications, which have sustainable project management as a subject of investigation, also prove the influence of this topic [6–8, 28, 29]. For this reason, the

Table 1 Sustainable project management definitions

Author	Definition
Silvius [23]	"Sustainable Project Management is the planning, monitoring and controlling of project delivery and support processes, with consideration of the environmental, economical and social aspects of the lifecycle of the project's resources, processes, deliverables and effects, aimed at realising benefits for stakeholders, and performed in a transparent, fair and ethical way that includes proactive stakeholder participation."
Carboni et al. [24]	"the application of methods, tools, and techniques to achieve a stated objective while taking into account the project outcome's entire lifecycle to ensure a net positive impact environmental, social, and economic impact"
Armenia et al. [25]	"the managerial practice aiming at pursuing project objectives by maximizing economic, social, and environmental benefits through the proactive involvement of stakeholders, the consideration of the extended life cycle of resources, processes, and effects, and continuous organizational learning"
Holzbaur [12]	"Sustainable project management is the consideration of sustainable development as a goal and framework for project management in the project office, in the selection and definition of the project, and throughout the project management process."
Brzozowska, Pabian and Pabian [26]	"an activity that consists in planning, organizing, leading, and controlling, carried out in accordance with the principles of sustainability, as a result of which the project team achieves project goals"

Table 2 Sustainability principles according to Silvius and Holzbaur [12, 23]

Principle 1	Sustainability is about balancing or harmonizing social, environmental and economical interests	All three dimensions of sustainability should be considered equally, as they influence each other In addition, according to the 2030 Agenda, partnerships should also be entered into and peace should be maintained
Principle 2	Sustainability is about both short-term and long-term orientation	Inter- and intragenerational equity The entire life cycle of actions should be considered, i.e. long and short-term effects
Principle 3	Sustainability is about local and global orientation	Actions have local and global impacts on all three dimensions of sustainability. These must be linked in the sense of sustainable development
Principle 4	Sustainability is about consuming income, not capital	Regeneration rate should not be exceeded
Principle 5	Sustainability is about transparency and accountability	The use of renewable resources should not exceed the rate of reproduction and the absorption capacity of the biosphere should not be exceeded (e.g. CO_2)
Principle 6	Sustainability is about values and ethics	Companies must be transparent with their actions, decisions and measures and accountable for environmental and social impacts

topic of sustainability is now also referred to as a new school of thought in project management [30] and is one of the most important global project management trends [5].

2.4 Project Success

Necessarily, when evaluating project success resulting from sustainable project management, the question arises of how project success can be measured concretely. Moreover, the understanding of project success has evolved over time. Initially, the criteria of the iron triangle were particularly used to evaluate project success. These have traditionally focused on time, cost and scope [31] or on time, cost and quality [32, 33]. In both scientific literature and practice, additional success criteria for projects have been identified over time, which can be considered in addition to the iron triangle. Ika has contrasted the development of criteria for measuring project success in the context of a study [34]. The development of the criteria for measuring project success is shown in Fig. 1 below:

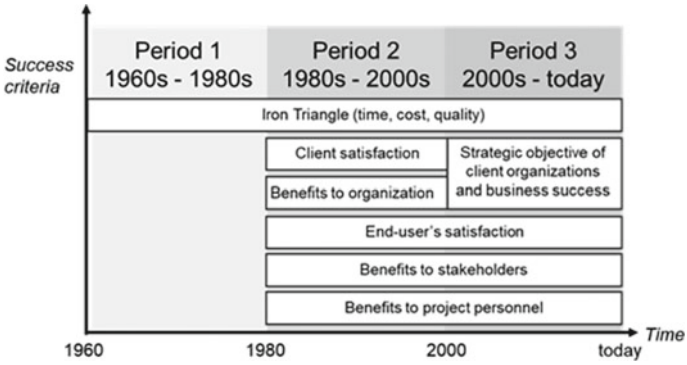


Fig. 1 Development of project success criteria based on Ika [34]

3 Course of the Investigation

In the following, we present the research question of this elaboration and the methodology.

3.1 Research Question

The number of scientific studies and literature reviews show that there are now a large number of scientific studies dealing with the topic of sustainable project management [6–8]. Nevertheless, there is insufficient scientific research available to investigate the relationship and impact of sustainable project management on project success [6, 35].

The analysis of Khalifeh, Farrell and Al-edenat [6] proves that previous studies have already found a positive impact of sustainable project management on project success, but the result was very different in the extent of the impact on project success [36–39]. In one study, the impact of sustainable project management on project success was uncertain [40]. The analyzed studies were subject to several limitations such as country and industry focus, research type and strategy, as well as the feedback received. It is concluded that future studies should rely more on surveys rather than case studies, as these are suitable for testing findings and hypotheses and thus building new knowledge. Future studies should also consider multiple stakeholders when assessing the success of the project [6]. The limitations and recommendations of previous studies, as well as the increasing importance of sustainability, invite to conduct a newer structured literature review and analyze the latest research findings regarding the relationship between sustainable project management and project success. Thus, the present study aims to answer the following research question:

RQ1: What influence does sustainable project management have on the success of the project?

3.2 Methodology

The essential in this study, a thorough and systematic literature review was conducted, resulting in a comprehensive selection of relevant literature. This literature was extracted, analyzed, and critically evaluated using transparent, well-organized, and repeatable steps to ensure the quality of the results [41]. The analysis was conducted following steps described by Fink for systematic literature review [42]. The defined research question RQ1 serves as a starting point. The next step is the selection of appropriate data sources. The main sources of literature examined are publications in peer-reviewed journals, with a focus on completed articles specifically related to the relationship between sustainable project management and project success. The Scopus scientific database was chosen as a source of literature due to its access to a wide range of publications authored by reputable scholars and experts in the field, making it a reliable source of scientific insights.

The search terms used were “sustainable project management” or “sustainability in project management” in combination with “success” or “performance”. The focus continued to be on articles that reflect the latest developments on the topic of sustainability. For this reason, articles were considered from 2020 until Feb. 17, 2023. This is also in line with the covered periods of previous studies, which covered articles until 2020 [6, 43].

The search string used in Scopus is: (TITLE-ABS-KEY ("sustainable project management"AND"success")ORTITLE-ABS-KEY ("sustainability in project management"AND"success")ORTITLE-ABS-KEY ("sustainable project management"AND"performance")ORTITLE-ABS-KEY ("sustainability in project management"AND"performance"))ANDPUBYEAR>2019AND(LIMIT-TO (DOCTYPE,"ar"))AND(LIMIT-TO (PUBSTAGE,"final")).

For data extraction of the full-text publications, scientific libraries such as Researchgate, MDPI, Semantic Scholar, and Academia were consulted. The initial population consisted of 19 studies, of which four were from 2020, ten were from 2021, and five were from 2022. No studies from 2023 (up to and including 17.02.2023) were identified that met the search criteria. In order to assess the search results further, the author analyzed the abstracts of the 19 studies in detail. Out of these, 15 studies were deemed irrelevant for this work as they did not primarily focus on the relationship between sustainable project management and project success. As a result, in the first step of the research, 4 studies were selected that had the relationship between sustainable project management and project success as their primary subject of investigation and thus were suitable for answering the research question. To expand the scope of our research, we also included sources of publications identified through the Scopus database, resulting in a total of 7 publications selected for this study.

The identified publications were subjected to a qualitative content analysis [44] and were thoroughly analyzed by the author and classified under different aspects to provide a holistic overview and answer the research question. The classification was based on the following criteria:

Table 3 Identified studies focusing on the relationship between sustainable project management and project success (Presentation of the author based on [35])

Studies	Nature of the study	Research method	Impact on project success	Industries covered	Geographical focus
Shaukat et al. [45]	Empirical	Survey (n = 323)	Positive	Construction, information technology, and telecommunication	Pakistan
Keshavarzian and Silvius [43]	Empirical	Survey (n = 132)	Positive	Across industries	Netherland
Chow et al. [46]	Empirical	Survey (n = 231)	Positive	Manufacture industries	Malaysia
Khan and Alam [47]	Empirical	Survey (n = 207)	Positive	Construction	Pakistan
Dubois and Silvius [35]	Empirical	Survey (n = 112)	Positive	Diverse	Europe
Malik et al. [48]	Empirical	Survey (n = 189)	Positive	Construction	Pakistan
Zaman et al. [49]	Empirical	Survey (n = 368)	Positive	Construction	Pakistan

1. The studies were structured according to the nature of study, research method, industries covered, and geographical location.
2. The studies were structured according the impact of sustainable project management on the project success

The identified studies are listed in the table below (Table 3):

4 Results

The study by [35] confirms in this respect the conclusions of [30] that sustainability in projects is mostly considered in connection with the project results and should not be viewed in isolation from the development and management process. Sustainable project management is perceived as an overall construct with differentiated effects on the various criteria of project success. Thus, the subjective perception of the positive relationship between project success and sustainable project management is not equally strong for all criteria. It is noteworthy at this point that the relationship between project success and the iron triangle of project management is less clear, suggesting that it apparently costs money to consider sustainability [43].

The fulfillment of the constraints of the project success criteria Cost, Time, Quality and Scope (iron triangle) show a high internal consistency to the satisfaction of the

stakeholders and the realization of the benefits [35]. However, [45] was able to find that the influence of stakeholder participation on the relationship between sustainable project management and project success is insignificant. The study also found that increased team building had no effect on the relationship between sustainable project management and project success. Other studies were also able to confirm a positive and significant influence of sustainable project management on project success [43, 47–49] and argues that sustainable project management can be seen as a key determinant of project success [46]. Nevertheless, at the same time, it was also found that the influence of sustainability on project success decreases with increasing project complexity [48].

Another study confirms that early integration of sustainability is also relevant for the success of a project. For example, a study of manufacturing companies confirmed that sustainable project planning as part of sustainable project management is an essential tool for project success and that this is influenced by it [46]. This makes it clear that sustainable project management should be considered at a very early stage of the project, as this can have an influence on the success of the project.

The connection between sustainable project management and a more controlled, on-time, on-budget, and fit-for-purpose completion of the project, as well as the realization of the planned project benefits and the satisfaction of the project participants, is also perceived positively by project managers. In addition, the positive impact of sustainable project management on preparing the organization for future challenges is also recognized by project managers [43].

Moreover, it was observed that recent studies have incorporated some of the recommendations made by Khalifeh et al. [6]. Survey was the most commonly used research method across all analyzed studies. While recent studies implemented the recommendation to analyze the impact of stakeholders on project success within the framework of sustainable project management [45], no significant relationship between these factors was identified. In this respect, the analyzed studies also confirm the results of previous studies, which, considering a wide variety of limitations and focuses, have provided similar trends [36–39]. Notably, the analyzed studies had a geographic focus on Pakistan and a sectoral focus on the construction industry, with four out of the seven studies concentrating on these regions and industries [45, 47–49].

In this regard, the research question raised as to how sustainable project management affects project success can be answered to the extent that it has a positive influence on project success. Nevertheless, the relationship of sustainable project management and project success has not yet been explored in its entirety and depth. Further studies need to be developed to investigate the relationship between sustainable project management and its financial and time impacts [43].

5 Conclusion

Through a thorough systematic literature review, the present study aimed to investigate the relationship between sustainable project management and project success, drawing on the latest studies available. The analysis of the publications revealed a noteworthy positive correlation between sustainable project management and project success. This outcome provides strong support for the implementation of sustainable project management practices in the pursuit of successful project outcomes, with important implications for both academics and practitioners alike.

The present study's findings corroborate previous research to a significant extent, affirming the positive correlation between sustainable project management and project success. Sustainable project management should refer to the application of sustainability principles and strategies in all phases of the project cycle. It has been shown that the integration of sustainability principles into project management can have a positive impact on project success. It can contribute to on-time, on-budget and on-purpose project completion as well as the realization of planned project benefits and satisfaction of project stakeholders. Ongoing monitoring identifies risks and uncertainties at an early stage by considering the environmental, economic and social impacts of the project. As a result, potential problems can be identified and resolved at an early stage, reducing risks and uncertainties. By reducing resource consumption and increasing resource efficiency, sustainable project management can also contribute to increased project efficiency and effectiveness. Although some studies indicate that incorporating sustainability into project management may incur additional costs [43], it is important to keep in mind that the cost of (partial) failure of the project may be much higher than the cost of incorporating sustainability.

Project managers and stakeholders have a common interest in ensuring that projects are completed successfully. It is therefore advisable to use all available opportunities to ensure the success of the project. Taking sustainability aspects into account in project management can help to increase project success. However, care must be taken to ensure that the overall cost of the project does not go over budget when sustainability is considered. Therefore, it is important to consider sustainability aspects as early as the project planning stage. Sustainability should be considered as an overall construct that spans the entire project, rather than as individual isolated measures. To ensure that sustainability aspects are continuously improved and developed, they should be regularly reviewed and adjusted as the project progresses. The consideration of sustainability in project management should therefore be seen as a long-term investment in the success of the project.

However, the focus of the analyzed studies on particular geographic and sectoral areas underscores the need for further inquiry. There is substantial room for future research to explore various geographic and sectoral contexts to determine if there are discrepancies in the link between project success and sustainable project management between developed and developing countries. This study provides a strong foundation for future researchers to build upon, and its findings contribute to a growing body of literature on the relationship between sustainability and project management.

References

1. Urikova, O., Ivanochko, I., Kryvinska, N., Zinterhof, P., Strauss, C.: Managing complex business services in heterogeneous eBusiness ecosystems—aspect-based research assessment. Procedia Comput. Sci. **10**, 128–135 (2012). https://doi.org/10.1016/j.procs.2012.06.020
2. Silvius, G., Schipper, R.: Sustainability in project management: a literature review and impact analysis. In: Social Business. Westburn Publishers Ltd, pp. 63–94 (2014)
3. GreenBiz Group. State of Green Business 2021 (2021)
4. Zukunftsinstitut. Megatrend-Map (2023)
5. Alvarez-Dionisi, L., Turner, R., Mittra, M.: Global project management trends. Int. J. Inf. Technol. Proj. Manag. **7**, 54–73 (2016). https://doi.org/10.4018/IJITPM.2016070104
6. Khalifeh, A., Farrell, P., Al-edenat, M.: The impact of project sustainability management (PSM) on project success: a systematic literature review. J. Manag. Dev. (2019). ahead-of-print: https://doi.org/10.1108/JMD-02-2019-0045
7. Sabini, L., Muzio, D., Alderman, N.: 25 years of 'sustainable projects'. What we know and what the literature says. Int. J. Proj. Manag. **37** (2019). https://doi.org/10.1016/j.ijproman.2019.05.002
8. Zakrzewska, M.: Sustainable Project Management Concept Development and Research Directions Review. Scientific Papers of Silesian University of Technology Organization and Management Series (2022). https://doi.org/10.29119/1641-3466.2022.157.45
9. Zielasek, G.: Was ist Projektmanagement? In: Zielasek, G. (ed.) Projektmanagement als Führungskonzept: Erfolgreich durch Aktivierung aller Unternehmensebenen. Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 6–12 (1999)
10. Kraus, G., Westermann, R.: Projektmanagement mit System: Organisation, Methoden. Gabler Verlag, Steuerung (2014)
11. Project Management Institute. A Guide to the Project Management Body of Knowledge (PMBOK Guide), 7th edn. Pennsylvania (2021)
12. Holzbaur, U.: Projekte für die Nachhaltigkeit. In: Holzbaur, U. (ed.) Nachhaltige Entwicklung: Der Weg in eine lebenswerte Zukunft, pp. 257–289. Springer Fachmedien Wiesbaden, Wiesbaden (2020)
13. Association for Project Management. APM Body of Knowledge, 7th edn. (2019)
14. International Project Management Association. IPMA Standards (2017)
15. Fedushko, S., Trach, O., Syerov, Y., Kryvinska, N., Calhoun J.R.: Web project development: emergency management. J. Web Eng. **21**, 2257–2286 (2022). https://doi.org/10.13052/jwe1540-9589.2182.
16. Kostalova, J., McGrath, J.: Sustainability in project management: two sides of the same coin or poles apart? (2021)
17. GPM Deutsche Gesellschaft für Projektmanagement e.V. Projektifizierung der Gesellschaft in Deutschland (2021)
18. Pufé, I.: Nachhaltigkeit. utb ; 8705 : Wirtschaftswissenschaften, Sozialwissenschaften (2017)
19. Brundtland, G.H.: Report of the World Commission on environment and development: our common future (1987)
20. Elkington, J.B.: Partnerships from cannibals with forks: the triple bottom line of 21st-century business. Environ. Qual. Manage. **8**, 37–51 (1998)
21. World Economic Forum. The Global Risk Report 2020 (2020)
22. World Economic Forum. The Global Risk Report 2023 (2023)
23. Silvius, G.: Sustainability in Project Management (Advances in Project Management) (2012)
24. Carboni, J., Milsom, P., Gonzalez, M., et al.: Sustainable Project Management. The GPM Reference Guide (2018)
25. Armenia, S., Dangelico, R.M., Nonino, F., Pompei, A.: Sustainable project management: a conceptualization-oriented review and a framework proposal for future studies. Sustainability **11** (2019). https://doi.org/10.3390/su11092664
26. Brzozowska, A., Pabian, A., Pabian, B.: Sustainability in Project Management—A Functional Approach (2021)

27. Holzbaur, U., Fierke, M.: Nachhaltige Entwicklung im Unternehmen. In: Holzbaur, U., Fierke, M. (eds.) Nachhaltiges Projektmanagement: Verantwortlichkeit und Umsetzung in zukunftsorientierten Organisationen, pp. 7–12. Springer Fachmedien Wiesbaden, Wiesbaden (2022)
28. Kiani Mavi, R., Gengatharen, D., Mavi, N., et al.: Sustainability in construction projects: a systematic literature review. Sustainability **13** (2021). https://doi.org/10.3390/su13041932
29. Magano, J., Silvius, G., e Silva, C.S., Leite, Â.: The contribution of project management to a more sustainable society: exploring the perception of project managers. Proj. Leadersh. Soc. **2**, 100020 (2021). https://doi.org/10.1016/j.plas.2021.100020
30. Silvius, G.: Sustainability as a new school of thought in project management. J. Clean. Prod. **166**, 1479–1493 (2017). https://doi.org/10.1016/j.jclepro.2017.08.121
31. Atkinson, R.: Project management: cost, time and quality, two best guesses and a phenomenon, its time to accept other success criteria. Int. J. Project Manage. **17**, 337–342 (1999). https://doi.org/10.1016/S0263-7863(98)00069-6
32. Agarwal, N., Rathod, U.: Defining 'success' for software projects: an exploratory revelation. Int. J. Project Manage. **24**, 358–370 (2006). https://doi.org/10.1016/j.ijproman.2005.11.009
33. Fortune, J., White, D.: Framing of project critical success factors by systems model. Int. J. Project Manage. **24**, 53–65 (2006). https://doi.org/10.1016/j.ijproman.2005.07.004
34. Ika, L.: Project success as a topic in project management journals. Proj. Manag. J. **40**, 6–19 (2009). https://doi.org/10.1002/pmj.20137
35. Dubois, O., Silvius, G.: The relation between sustainable project management and project success. Int. J. Manag. Sustain. **9**, 218–238 (2020). https://doi.org/10.18488/journal.11.2020.94.218.238
36. Carvalho, M.M.: Sustainability and success variables in the project management context: an expert panel. Proj. Manag. J. **47**, 24–43 (2016). https://doi.org/10.1177/875697281604700603
37. Martens, M.L., Carvalho, M.M.: The challenge of introducing sustainability into project management function: multiple-case studies. J. Clean. Prod. **117**, 29–40 (2016). https://doi.org/10.1016/j.jclepro.2015.12.039
38. Khalilzadeh, M., Akbari, H., Foroughi, A.: Investigating the relationship of sustainability factors with project management success. Ind. Eng. Manag. Syst. **15**, 345–353 (2016)
39. Carvalho, M.M., Rabechini, R.: Can project sustainability management impact project success? An empirical study applying a contingent approach. Int. J. Project Manage. **35**, 1120–1132 (2017). https://doi.org/10.1016/j.ijproman.2017.02.018
40. Adriana, T.-T., Ioana-Maria, D.: Project success by integrating sustainability in project management. In: Silvius, G., Tharp, J. (eds.) Sustainability Integration for Effective Project Management. IGI Global, Hershey, PA, USA, pp. 106–127 (2013)
41. Tranfield, D., Denyer, D., Smart, P.: Towards a methodology for developing evidence-informed management knowledge by means of systematic review. Br. J. Manag. **14**, 207–222 (2003). https://doi.org/10.1111/1467-8551.00375
42. Fink, A.: Conducting Research Literature Reviews: From the Internet to Paper. Sage Publications (2019)
43. Keshavarzian, S., Silvius, G.: The perceived relationship: between sustainability in project management and project success. J. Mod.Proj. Manag. **10**, 66–85 (2022). https://doi.org/10.19255/JMPM02805
44. Duriau, V., Reger, R., Pfarrer, M.: A content analysis of the content analysis literature in organization studies: research themes, data sources, and methodological refinements. Organ. Res. Methods **10**, 5–34 (2007). https://doi.org/10.1177/1094428106289252
45. Shaukat, M.B., Latif, K.F., Sajjad, A., Eweje, G.: Revisiting the relationship between sustainable project management and project success: the moderating role of stakeholder engagement and team building. Sustain. Dev. **30**, 58–75 (2022). https://doi.org/10.1002/sd.2228
46. Chow, T.C., Zailani, S., Rahman, M.K., et al.: Impact of sustainable project management on project plan and project success of the manufacturing firm: structural model assessment. PLoS ONE **16** (2021). https://doi.org/10.1371/journal.pone.0259819

47. Khan, I., Alam, A.: The collaborative effect of sustainable project management (SPM) and benefits management (BM) on project success: with the influencing force of project governance (2020)
48. Malik, M.F., Khan, R.A., Khan, M.M., Humayon, A.A.: Role of sustainability and project complexity in achieving project success. City Univ. Res. J. (2020)
49. Zaman, U., Abbasi, S., Nawaz, M., Siddique, M.: Linking sustainability management and success in construction projects: moderating influence of high performance work systems. Pak. J. Commer. Soc. Sci. **14**, 661–684 (2020)

Data Science for Social Climate Change Modelling: Emerging Technologies Review

Taras Ustyianovych

Abstract Climate change is one of the most acute global problems, the consequences of which are becoming more and more noticeable every year and are the subject of scientific debate, as well as discussions in business and society. Advanced tools for modeling and forecasting not only the physical indicators of this problem, but also the social, economic, and biological-evolutionary ones are necessary to reduce risks and gain control over the situation. This paper focuses on the social factors of climate change and their modeling and assessment since it is the involvement of society that is crucial in the implementation and enforcement of relevant initiatives, policies, and legislation. A review of methods and tools for such modeling and forecasting will allow us to analyze their evolution and identify the most effective ones in terms of accuracy and resource use. Particular attention is paid to the topic of multimodal data fusion because the problem of climate change in many aspects, including social, is multidimensional and caused by the cumulative effect of many factors. This paper emphasizes the importance of synthesizing climate and social data streams for evidence-based policymaking. The presented frameworks can be extended to broader applications in socio-ecological modeling and decision support systems.

Keywords Climate change · Multimodal data · Data fusion · Data science · Social response modelling · Review

1 Introduction

The climate crisis is becoming more and more acute every day and requires immediate decisive action. This problem is multifaceted, as it depends on a set of interrelated factors and poses an unpredictable threat [1–3]. Accordingly, climate change assessment and modeling requires a consolidated approach that takes into account all or

T. Ustyianovych (✉)
Lviv Polytechnic National University, Lviv, Ukraine
e-mail: taras.o.ustyianovych@lpnu.ua

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2024

P. Štarchoň et al. (eds.), *Data-Centric Business and Applications*, Lecture Notes on Data Engineering and Communications Technologies 213,
https://doi.org/10.1007/978-3-031-62213-7_18

at least most of the key factors, which will allow for an assessment of causes and consequences from different perspectives. One of the crucial aspects is the readiness of public institutions to take measures to overcome the climate crisis, which involves a transition to a sustainable and environmentally friendly way of life. Artificial intelligence systems can become an effective tool for modeling both physical climate processes and the level of public awareness and perception of the problem. Thanks to their data processing capacities, such systems are able to analyze huge amounts of information and identify hidden connections. However, the use of only one type of data does not provide a holistic view of the depth of the climate crisis. Therefore, it is critical to consolidate data from different formats and sources that directly or indirectly affect climate change and integrate them using artificial intelligence and machine learning [4, 5].

The problem of climate change has resonated with society, which is manifested in the publication of posts on social media and web communities, scientific and popular science works, the implementation of climate policies and legislation, the media, podcasts, and art [6–11]. This serves as another confirmation that this problem has become a matter of global discussion. However, understanding the trends in the creation and dissemination of these types of information, their perception in society, and their real impact on the climate situation often remains unclear. Of course, well-established climate initiatives often contain calculations with the specified environmental impact and contribution to solving the climate crisis. At the same time, the real situation is much more complex than a certain model and contains an error. It is worth noting the need to take into account the public perception of a certain initiative and understanding of the expected number of people involved in order to bring about real climate change. Accordingly, validating the error, supplementing it with external data, and studying public opinion and reaction will allow the creation and implementation of realistic and at the same time significant eco-initiatives and projects to solve the problem.

Given the availability of data and information on climate change, physical indicators and metrics, as well as documented discussions on the Internet and various types of publications, analytics are carried out using a variety of methods and tools, including artificial intelligence. At the same time, the potential of this data is significant, and the number of tasks that need to be solved continues to grow. In particular, specific modelling tasks for the climate problem and its aspects require innovative and integrated approaches. These include the usage of large language models and multimodal data fusion [12, 13].

From the perspective of studying social perceptions of climate change, primarly single-modal data sources (e.g., social media posts) are taken into account for text mining [14]. Multimodal data fusion using deep neural networks has been successfully used or to solve such practical problems related to climate change as wildfire detection and water biodiversity research [15, 16]. Therefore based on the analysis of certain studies in this subject area, most studies focused on social indicators of the climate crisis using multimodal data are either absent or theoretically oriented. Therefore, the application of climate information fusion for social perceptions, eco-initiatives, legislation, and publications research will help improve the efficiency

of modeling physical, social, and economic indicators of climate change. Thus, the forecasting accuracy will improve, since the fusion of data from different sources improves the quality of training sets for climate models. The presence of multimodality will allow the prediction of a wide range of features depending on the fusion result and not be limited to a single set of dependent variables. For example, a multimodal dataset consisting of text publications and satellite imagery and geospatial data related to a particular natural phenomenon will facilitate the solution of the following tasks using data science technologies:

(1) identify hidden and non-obvious relationships between textual, social, and climate data—combining weather, environmental, media, and social data can highlight non-obvious correlations;
(2) model the impact and perception of information in the media depending on the spread of a natural phenomenon caused by climate change;
(3) generate content for publication based on predictive models of natural phenomenon trends and previously published content.

The purpose of this article is to provide a comprehensive review of state-of-the-art methods and models using multimodal data fusion to address climate change, to study public perception and public discussion of this issue, and to analyze and calculate the effectiveness of public eco-initiatives, legislation, and events related to this topic. To achieve the research goal, the following tasks are to review methods and tools for multimodal fusion of metric, text, image, video, and sensor data for analysis of climate change perspectives and sentiment; to formulate requirements for sets and sources of information for multimodal fusion of climate and social data; to identify leading computational algorithms and models for processing multimodal data on the climate crisis and its social perception; to compare the effectiveness and accuracy of the results obtained in current works.

The result of this study is to identify the requirements, methods, and tools for multimodal data fusion to address climate change and model its social perception. The current picture of scientific solutions and developments in this area is formed and the features of those works that give the maximum result are highlighted. The author proposes advancements based on the studied works for multimodal fusion and social factors modeling for optimization of the environmental situation.

2 Materials and Methods

A fundamental work that substantiates the need and ways to involve society in addressing the climate crisis is presented in the study by Otto et al. [17]. It contains a clear definition of the social tipping dynamics, intervention (STI), and element (STE) terms. An important focus is made on the latter two, as STI is a tipping point triggering drastic and breakthrough changes in a specific process (global greenhouse gas emissions reduction), while STEs are sectors of the planetary socio-economic system integrated into society that play a role in the climate situation (industrial

complex, norms and values systems, financial markets). STI can influence STE and vice versa, making these two variables interdependent. Their usage is promising in the climate change subject for modeling, analysis, and forecasting tasks using data science, data fusion, and deep learning. These technologies will improve our knowledge of leverage points where small changes can catalyze system transformations. This knowledge is crucial to addressing the urgency of climate change through social action. So, the identified social tipping elements highlight opportunities for fusing multimodal data like social media, remote sensing, and surveys to model system evolutions. Predicting the occurrence of social tipping intervention under specific input parameters of the system will allow for timely response in a limited time frame to prevent the onset of critical climate anomalies. Therefore, solving such problems requires data multimodality to comprehensively cover various social tipping elements and combine climate indicators. Therefore, this research lays an vital foundation for leveraging data science and multimodal data integration to identify social leverage points and guide the rapid systemic change needed for climate mitigation and adaptation. The framework presented generates valuable insights and research questions to further the application of computational methods for understanding climate-society dynamics. The review of studies related to the research topic involves searching for them in scientific databases, journals, and with search engines. At this stage, a search query will be formed to select the most relevant research papers. The found publications are proposed to be selected using the PRISMA methodology. Relevant publications are reviewed with the extraction of key results, used and developed methods. Particular attention should be paid to (1) the data collection procedure and information resources used; (2) the fusion of multimodal data; (3) the presence of modalities related to the social perception of the climate problem; (4) computational algorithms and models; (5) the results obtained and their practical application. Most of the studies in this research field focus on predicting physical and climate-related indicators with the help of mathematical, statistical, and deep learning models. Whereas studies with primary focus on the social aspect of cliamte change study public discourse lack multimple modalities and data science background.

The social stance towards climate change is becoming even more relevant today, where the consequences of the abovementioned climate problems are tangible on a daily basis, there is a tendency to increase the average temperature of the Earth's surface, and natural disasters occur. At the same time, geopolitical events (Russian aggression against Ukraine, and Israeli military operations in the Gaza Strip) not only harm the environment but also have a direct or indirect impact on social perception of environmental issues and the energy sector. These events are a significant factor and driver of social processes related to the climate crisis. Certain legislative eco-initiatives and innovations receive social feedback, which will help convey a message to the target audience, and take into account opportunities for climate policies improvement. Such move, in turn, will contribute to building a climate problem-aware society that is engaged in solving the climate crisis and caring for the environment. The ability of artificial intelligence methods and tools to process relevant data will be improved using multimodal fusion, allowing for better modeling

and understanding of social processes, predicting tipping points that will have a breakthrough impact on handling the climate situation and reducing CO_2 emissions.

The PRISMA method was used to comprehensively and thoroughly review scientific papers relevant to the topic of social research on climate change using data science, machine intelligence, and multimodal data processing. The search was conducted in the scientometric and research databases Scopus and IEEE Xplore. These resources were chosen for the following reasons: very large databases of peer-reviewed literature covering science, technology, medicine, social sciences, arts, and humanities; provide regular updates of newly published literature; include journals, conference proceedings, books, patents; offer usable and advanced search and filtering capabilities; a variety of publications related to the research subject. IEEE Xplore is considered a leading scientific database for electrical engineering, computer science, and related fields, whereas Scopus has conscientiously reviewed content from more than 7000 publishers.

The following search query was used to search SCOPUS:

```
((TITLE-ABS-KEY (climate) OR TITLE-ABS-KEY(ecology) OR TITLE-ABS-KEY("sustainable development")) AND (TITLE-ABS-KEY("data science") OR TITLE-ABS-KEY("machine learning") OR TITLE-ABS-KEY("machine intelligence") OR TITLE-ABS-KEY("language model") OR TITLE-ABS-KEY("artificial intelligence") OR TITLE-ABS-KEY(multimodal) OR TITLE-ABS-KEY("deep learning")) AND (TITLE-ABS-KEY(social) OR TITLE-ABS-KEY(society) OR TITLE-ABS-KEY(human))) AND PUBYEAR > 2018 AND PUBYEAR < 2025
```

The results of the PRISMA search are shown in the figure below (Fig. 1).

The IEEE Xplore database has a separate section dedicated to climate change called the IEEE Climate Change Collection. Additional filtering of the results by years of publication from 2019 to 2024 inclusive has been performed.

Using the PRISMA method, we managed to select 51 papers, the results of which are summarized in Table 1 below.

Based on the analysis of these papers, the following conclusions have been drawn about recent research in the use of Data Science for climate change research:

- the target audience for using the results in most studies is policymakers who formulate regulations and laws to address climate change and interact with the public;
- studies with a focus on text processing are limited to a single modality, usually discussions of social media users, publications in news and scientific journals;
- the main NLP tasks solved with text climate data are topic modeling, classification, and sentiment detection;
- predictive models using multimodal data are aimed at solving practical problems and issues related to the climate crisis (wildfire detection, extreme rainfall forecasting, air quality assessment, natural disasters prediction, food security modeling);
- 36% of the analyzed papers use or propose the usage of multimodal data, and text data is one of the modalities;

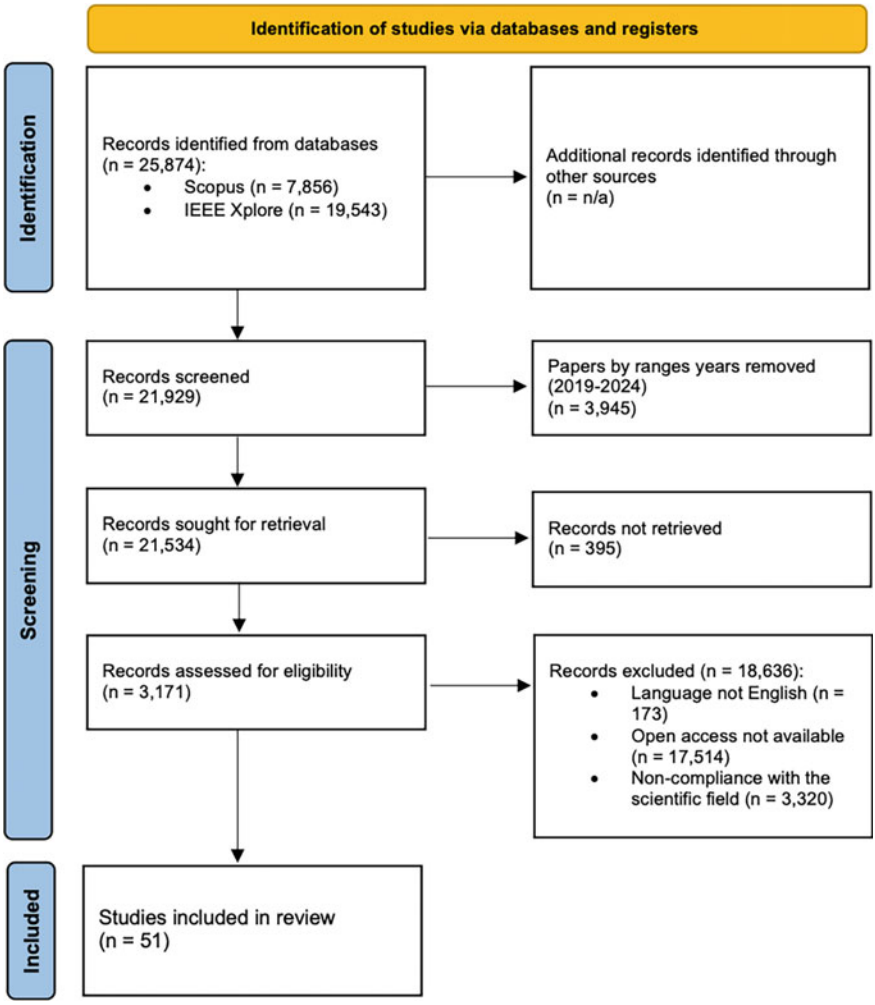


Fig. 1 PRISMA records identification methodology for Scopus and IEEE Xplore databases

- the main data types in multimodal fusion are satellite imagery, geospatial data, and metric data;
- the study of social perception of the climate problem is based on data from social media discussions and surveys;
- five pieces of research apply mathematical modeling to determine information impact, social awareness, and support the decision-making in the development of climate policies and the implementation of sustainable technologies.

Figure 2a shows a breakdown of the generalized methods used in the analyzed studies for data processing. Each paper could use several approaches, and each of

Table 1 Studies review on data science usage for climate change modeling and social understanding collected by PRISMA methodology

Domain	Studies description	Methods leveraged	Data sources	Points for improvement
Climate and environment modeling with multimodal data	Integrating diverse data sources such as land cover, urbanization patterns, and climate simulations through multimodal frameworks enhances the accuracy of climate impact projections and extreme event forecasting [18–21]. Additionally, combining factual climate knowledge, critical literature reviews, and domain expertise facilitates building ontologies and narratives to represent climate change holistically [22–24]. Using multimodal data fusion to jointly analyze weather, climate, and air quality data also provides new insights and improves the overall understanding of climate phenomena [24–28]	Neural networks and deep learning of varying complexities; data fusion frameworks; data representation methods; state-of-the-art transformers; affinity propagation algorithm; topic modeling and clustering analysis	Satellite imagery and geospatial datasets; metric data on climate change; factual text-based information on climate change including literature reviews, news, theories, social and political initiatives	Provide detailed methodology for data fusion and processing of multi-modal data; increase the variety of data sources and expand the geography of research for comparative studies
Climate-related text processing	Social media text mining allows analyzing public opinion on climate change happenings and policies [29–32]. Topic models have proven to be an effective tool to track climate-related issues in text data over time [33–36]. NLP Transformer performs better compared to conventional lexicon-based models for identifying climate stances from short social media text [14, 37, 38]	Topic modeling algorithms; NLP transformers; Hilbert space-filling curves and knowledge graphs	Social media data, business news, research publications, bibliometric analysis representing databases	Expansion beyond textual data could lead to new insights and improve modeling performance

(continued)

Table 1 (continued)

Domain	Studies description	Methods leveraged	Data sources	Points for improvement
Data-driven approaches for climate action and sustainable development policies creation	Reviews reveal research gaps for AI in climate action [39, 40]. Mathematical models combined with surveys and simulations help determine influential factors and optimal strategies for climate policymaking [41–47]. Analyzing energy, emissions, economic and social data provides an evidence base for planning climate mitigation pathways [48–55]	Agent-based models and reinforcement learning; mathematical modeling; quantitative and qualitative research; multicriteria decision-making methods	Academic literature, scientific publications, climate-related policies, and reports; survey data; data from opinion gathering and questionnaires; energy and air quality data from official data sources	Assess tangible policy impacts and evaluate how the implemented policies affect the climate situation
Misinformation detection on climate change topics	Analyzing the spread of misinformation on social media helps to understand polarization and radicalization dynamics [56]. A recent fake news detection model built using transformer networks and handcrafted features can achieve F1 scores of up to 85% on classifying climate misinformation [57]	Machine learning models of varying complexity, transformer-based models; and mathematical modeling	Social media data; manually labeled dataset with articles on climate change	Features extraction to enhance misinformation detection; utilization of zero-shot classification or few-shot learning for automated data labeling with a human-in-the-loop; collection of more data for model training

(continued)

Table 1 (continued)

Domain	Studies description	Methods leveraged	Data sources	Points for improvement
Initiatives and technological approaches for handling climate change	Social media data can be effectively used to make frugal and eco-friendly decisions [58]. Factors influencing the decision to adopt a sustainable solution for smart cities and individual institutions are discussed [59, 60]	Probabilistic modeling and similarities computation; clustering analysis; quantitative and qualitative research	Social media data; research articles and experts' opinion data	Expand the data scope; consider the possibility of merging all three mentioned data for a consolidated study
Modeling the social dimensions of climate change	The studies find a correlation between social behavior and awareness levels in climate-friendly decision-making [61]; and perform analysis and prediction of social stance towards climate change topics including the use of image data [62–65]. Also, another research focuses on using artificial intelligence to improve the development of educational ecology [66]	Sentiment analysis, single-label, and multi-label classification, multi-task learning; mathematical modeling, and statistical analysis	Social media image data; financial, technological, and infrastructure indicators; data collected from questionnaires	Highlight how specific models and initiatives can be improved using artificial intelligence. Expand emotive analysis beyond sentiment. It might be worth providing a comprehensive explanation of the multi-task learning implementation details

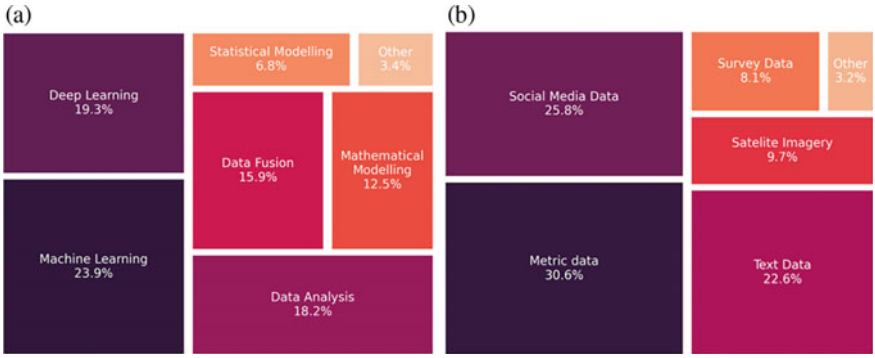


Fig. 2 **a** Methods and **b** data types used in the reviewed studies of data science research for social climate change

them was taken into account when preparing these statistics. According to the results, classical machine learning methods are the most common (23.9%), as they are well suited to solving data classification and clustering problems and do not require significant computing power. Deep learning was applied in 19.3% of the analyzed papers, including state-of-the-art NLP transformers, which were often combined with data fusion approaches (15.9%). Also, deep learning was used in studies to analyze satellite imagery and geospatial data, as it is a suitalbe and advanced technology for intelligent processing. Mathematical (12.5%) and statistical (6.8%) modeling remain helpful tools for comparing the performance with other methods and developing decision-making support models. Data Analysis methods account for 18.2% and include the study of scientific publications, policies and regulations, are used to calculate descriptive statistics and perform basic mathematical operations and aggregation.

The distribution of data sources used in the studies is shown in Fig. 2b. The most common data type was metric data (30.6%), collected using sensors, laboratory equipment, or other devices and mostly presented in tabular form. They are helpful for analyzing patterns and trends in the dynamics, such as rainfall over a certain period, air quality, economic, social, and physical indicators related to climate change. Social media data (25.8%) also accounted for the lion's share and included posts, comments, and media content from platforms such as Twitter or Reddit. This source is crucial for examining social perceptions of climate change. Also, social media data can serve as vital source of events and new information about certain climate disasters and provide real-time information about the climate situation in a particular region. The correlation of such data with physical climate indicators is a valuable addition to study both in the short-term (e.g., the spread of forest fires or other climate disasters) and long-term (the impact of social trends on climate policymaking, the initiation and development of global climate initiatives) perspectives. The third position belongs to text data (22.6%), which primarly includes documents of state policies in the field of climate change, news articles, and scientific publications. This data type

presented separately from the previous one, as its writing and presentation styles, features, and the target audience may differ. Thus, these text data are valuable as an additional modality that serves as a resource for studying and modeling the climate situation in scientific, business, social, and public environments. Satellite images and geospatial information were processed in 9.7% of the analyzed papers. This data sources provides a direct ability to observe the effects of climate change and measure its physical indicators. As mentioned above, the correlation of these data types with social media and text data will allow us to assess whether there are effects from climate policies and sustainable solutions and how they affect the environment and reduce greenhouse gas emissions. The smallest share (8.1%) consisted of data from surveys on climate change issues and other data types (3.2%), such as video data and expert information.

The following contingency table in the form of a graph in Fig. 3 with percentage values demonstrates the distribution of data types and methods usage between each other. Based on this information, the following observations can be made:

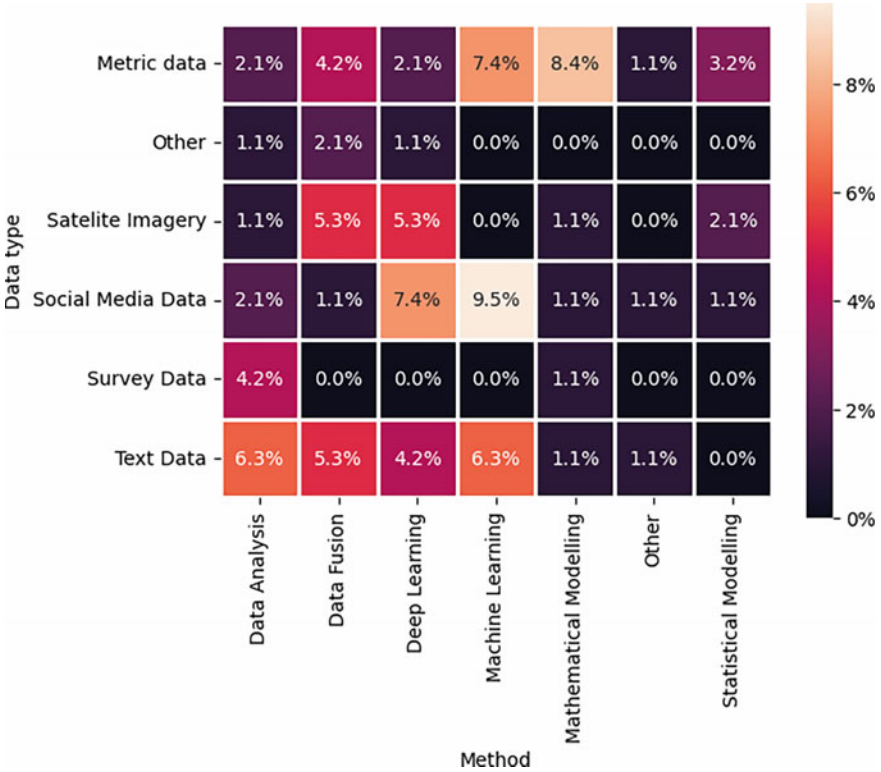


Fig. 3 Contingency table presented with percentage values between methods and data types used in the analyzed studies

- Metric data was most often processed using machine learning, mathematical and statistical modeling methods. It is worth noting that this data type was also used in data fusion tasks.
- Satellite imagery and geospatial information were used with approximately equal frequency for data fusion and training of deep neural networks.
- Machine learning and deep learning are leading the way in processing social media data. Traditional data mining has also been applied as a way to extract knowledge from this data type, but somewhat less frequently than the previous two methods.
- Data analysis and mathematical modeling were used to process the survey data.
- Text data has been subjected to a variety of processing approaches: from data fusion methods for integrating data and forming datasets to analyzing, modeling, and predicting with data analytics, machine learning, and deep learning techniques.
- Other data types can also be a valuable source for fusing data and performing climate research.

The value of the studied works is their representation of a historical and up-to-date pictures of the climate problem public understanding. However, there are no tasks where the perception information is fused with the actual climate situation, forecasting its development trends and abrupt changes in the long-term, or determining the conditions for the onset of such a change or the social tipping intervention. The methods that data science has in its arsenal are primary and the most suitable for conducting such research and solving relevant problems. The development of scalable algorithms will allow not only qualitative and quantitative assessment of current social stance, but also forecasting the involvement of society in eco-initiatives and model their impact on the climate situation depending on the input parameters.

3 Results

The results of the review of works that reflect the types of data and methods allow us to form a picture of the most common approaches for theoretical and practical research using data science for social climate change. Based on the information studied, it is proposed to pay more attention to the consolidation of heterogeneous data through the development of new data fusion methods, which will create more representative and informative data sets. As of now, multimodal fusion is mainly used to study physical indicators. Therefore, it is advisable to expand the use of multimodal data, in particular the combination of textual, metric, visual and geospatial information, and social media data for in-depth analysis and study of cause and effect processes.

More attention should be paid to the development of specialized workflows and frameworks for analyzing social media data in the context of climate change research. This will allow for more structured data processing, data merging, and knowledge mining about public attitudes and the effects of climate change. According to the analyzed studies, mathematical modeling has proven to be a promising and reliable

method in supporting decision-making in the development of climate policies and initiatives. Their use, along with machine learning algorithms and large language models, can prove to be an effective assistant in addressing climate change. The results of the research analysis indicate a lack of comprehensive practical implementations using a multimodal data types and approaches to the analysis and extensive study of social climate issues.

4 Conclusions

A careful study of recent trends in data science for social climate change research has led to the following general statements:

- hybrid approaches combining multimodal data sources, mathematical models, and AI methods are promising for integrated climate-social analysis;
- strategic climate policy formulation requires evidence from both simulation models and empirical data synthesis;
- multimodal data frameworks enhance early warning and preparedness for climate hazards and can be effectively used to identify critical social tipping points and help promote climate-friendly approaches.

Further research in this area will ensure the qualitative identification and modeling of social tipping points and ways to achieve them. Increasing social engagement through data science technologies, statistical and mathematical methods is tangible. This will deepen the understanding of social tipping elements, their relationship to the climate situation and social perception and understanding of interconnections, systems, and issues. Legal regulation of the environmental situation and the climate crisis that takes into account this information, as well as data on events and consequences related to the climate crisis, will ensure high-quality decision-making to respond to anomalies and formulate appropriate initiatives and increase public engagement and positive feedback. Advanced technologies of large-scale language models can contribute to the development of an effective policy to respond to the climate crisis through the analysis of public opinion. The issue of assessing and modeling the effectiveness of implementing eco-initiatives in society regarding climate change, in particular how it affects the minimization of CO_2 emissions, remains open. Therefore, a holistic view of a multifaceted problem can be achieved by combining social, economic, and climate data, which provides a comprehensive and inclusive view of the subject matter. Harnessing synergies across tipping interventions and elements could help overcome barriers and accelerate the sustainability transformations needed to mitigate climate change. Significantly, this study underscores the urgency of multimodal data processing with an account for the social aspects of the subject to guide intentional systemic change toward climate-resilient futures.

References

1. Kumar, A., Nagar, S., Anand, S.: Climate change and existential threats. Glob. Clim. Chang. 1–31 (2020). https://doi.org/10.1016/B978-0-12-822928-6.00005-8
2. Xian, X., Zhao, H., Wang, R., Huang, H., Chen, B., Zhang, G., Liu, W., Wan, F.: Climate change has increased the global threats posed by three ragweeds (Ambrosia L.) in the Anthropocene. Sci. Total. Environ. **859**, 160252 (2023). https://doi.org/10.1016/j.scitotenv.2022.160252
3. Zhang, Q., Shen, Z., Pokhrel, Y., et al.: Oceanic climate changes threaten the sustainability of Asia's water tower. Nature **615**, 87–93 (2023). https://doi.org/10.1038/s41586-022-05643-8
4. Steyaert, S., Pizurica, M., Nagaraj, D., et al.: Multimodal data fusion for cancer biomarker discovery with deep learning. Nat. Mach. Intell. **5**, 351–362 (2023). https://doi.org/10.1038/s42256-023-00633-5
5. Pawłowski, M., Wróblewska, A., Sysko-Romańczuk, S.: Effective techniques for multimodal data fusion: a comparative analysis. Sensors **23**(5), 2381 (2023). https://doi.org/10.3390/s23052381
6. Clayton, S.D., Pihkala, P., Wray, B., Marks, E.: Psychological and emotional responses to climate change among young people worldwide: differences associated with gender, age, and country. Sustainability **15**(4), 3540 (2023). https://doi.org/10.3390/su15043540
7. Maibach, E.W., Uppalapati, S.S., Orr, M., Thaker, J.: Harnessing the power of communication and behavioral science to enhance society's response to climate change (2023). https://doi.org/10.1146/annurev-earth-031621-114417
8. Garrido, I., L´Hotellerie-Fallois, P., Santillan Fraile, J.: Climate Change and Sustainable Growth: International Initiatives and European Policies (El Cambio Climático Y La Sostenibilidad Del Crecimiento: Iniciativas Internacionales Y Políticas Europeas). Banco de Espana Occasional Paper No. 2213 (2023). Available at SSRN: https://ssrn.com/abstract=4344764
9. Chen, K., Molder, A.L., Duan, Z., Boulianne, S., Eckart, C., Mallari, P., Yang, D.: How climate movement actors and news media frame climate change and strike: evidence from analyzing Twitter and news media discourse from 2018 to 2021. Int. J. Press./Politics. (2022). https://doi.org/10.1177/19401612221106405
10. https://www.bbc.com/news/science-environment-24021772
11. https://climate.nasa.gov/
12. Alipour, M., La Puma, I., Picotte, J., Shamsaei, K., Rowell, E., Watts, A., Kosovic, B., Ebrahimian, H., Taciroglu, E.: A multimodal data fusion and deep learning framework for large-scale wildfire surface fuel mapping. Fire **6**(2), 36 (2023). https://doi.org/10.3390/fire6020036
13. Cammarano, D., Olesen, J.E., Helming, K., et al.: Models can enhance science-policy-society alignments for climate change mitigation. Nat. Food **4**, 632–635 (2023). https://doi.org/10.1038/s43016-023-00807-9
14. Müller-Hansen, F., Repke, T., Baum, C.M., Brutschin, E., Callaghan, M.W., Debnath, R., Lamb, W.F., Low, S., Lück, S., Roberts, C., Sovacool, B.K., Minx, J.C.: Attention, sentiments and emotions towards emerging climate technologies on Twitter. Glob. Environ. Chang. **83**, 102765 (2023). https://doi.org/10.1016/j.gloenvcha.2023.102765
15. Alipour, M., La Puma, I., Picotte, J., Shamsaei, K., Rowell, E., Watts, A., Kosovic, B., Ebrahimian, H., Taciroglu, E.: A multimodal data fusion and deep learning framework for large-scale wildfire surface fuel mapping. Fire **6**, 36 (2023). https://doi.org/10.3390/fire6020036
16. Gambín, Á.F., Angelats, E., González, J.S., Miozzo, M., Dini, P.: Sustainable marine ecosystems: deep learning for water quality assessment and forecasting. IEEE Access **9**, 121344–121365 (2021). https://doi.org/10.1109/ACCESS.2021.3109216
17. Otto, I.M., Donges, J.F., Cremades, R., Bhowmik, A., Hewitt, R.J., Lucht, W., Rockström, J., Allerberger, F., McCaffrey, M., Doe, S.S., Lenferna, A., Morán, N., Van Vuuren, D.P., Schellnhuber, H.J.: Social tipping dynamics for stabilizing Earth's climate by 2050. Proc. Natl. Acad. Sci. **117**(5), 2354–2365 (2020). https://doi.org/10.1073/pnas.1900577117

18. Muñoz, D.F., Muñoz, P., Alipour, A., Moftakhari, H., Moradkhani, H., Mortazavi, B.: Fusing multisource data to estimate the effects of urbanization, sea level rise, and hurricane impacts on long-term wetland change dynamics. IEEE J. Sel. Top. Appl. Earth Obs. Remote. Sens. **14**, 1768–1782 (2021). https://doi.org/10.1109/JSTARS.2020.3048724
19. Kazemi Garajeh, M., Salmani, B., Zare Naghadehi, S., et al.: An integrated approach of remote sensing and geospatial analysis for modeling and predicting the impacts of climate change on food security. Sci. Rep. **13**, 1057 (2023). https://doi.org/10.1038/s41598-023-28244-5
20. Xie, Z., Yang, Y., Zhang, Y., et al.: Deep learning on multi-view sequential data: a survey. Artif. Intell. Rev. **56**, 6661–6704 (2023). https://doi.org/10.1007/s10462-022-10332-z
21. Ntinopoulos, N., Sakellariou, S., Christopoulou, O., Sfougaris, A.: Fusion of remotely-sensed fire-related indices for wildfire prediction through the contribution of artificial intelligence. Sustainability **15**, 11527 (2023). https://doi.org/10.3390/su151511527
22. Pileggi, S.F., Lamia, S.A.: Climate change timeline: an ontology to tell the story so far. IEEE Access **8**, 65294–65312 (2020). https://doi.org/10.1109/ACCESS.2020.2985112
23. Hunter, S.B., Mathews, F., Weeds, J.: Using hierarchical text classification to investigate the utility of machine learning in automating online analyses of wildlife exploitation. Eco. Inform. **75**, 102076 (2023). https://doi.org/10.1016/j.ecoinf.2023.102076
24. Văduva, A.-G., Munteanu, M., Oprea, S.-V., Bâra, A., Niculae, A.-M.: Understanding climate change and air quality over the last decade: evidence from news and weather data processing. IEEE Access **11**, 144631–144648 (2023). https://doi.org/10.1109/ACCESS.2023.3345466
25. Antonelli, A., Dhanjal-Adams, K.L., Silvestro, D.: Integrating machine learning, remote sensing and citizen science to create an early warning system for biodiversity. Plants, People, Planet **5**(3), 307–316 (2023). https://doi.org/10.1002/ppp3.10337
26. Liz-López, H., Huertas-Tato, J., Pérez-Aracil, J., Casanova-Mateo, C., Sanz-Justo, J., Camacho, D.: Spain on fire: A novel wildfire risk assessment model based on image satellite processing and atmospheric information. Knowl.-Based Syst. **283**, 111198 (2024). https://doi.org/10.1016/j.knosys.2023.111198
27. Halder, B., Ahmadianfar, I., Heddam, S., et al.: Machine learning-based country-level annual air pollutants exploration using Sentinel-5P and Google Earth Engine. Sci. Rep. **13**, 7968 (2023). https://doi.org/10.1038/s41598-023-34774-9
28. Vitanza, E., Dimitri, G.M., Mocenni, C.: A multi-modal machine learning approach to detect extreme rainfall events in Sicily. Sci. Rep. **13**, 6196 (2023). https://doi.org/10.1038/s41598-023-33160-9
29. Roldán-álvarez, D., Martínez-Martínez, F., Martín, E., Haya, P.A.: Understanding discussions of citizen science around sustainable development goals on Twitter. IEEE Access **9**, 144106–144120 (2021). https://doi.org/10.1109/ACCESS.2021.3122086
30. Qazi, A., et al.: Toward sustainable energy: a systematic review of renewable energy sources, technologies, and public opinions. IEEE Access **7**, 63837–63851 (2019). https://doi.org/10.1109/ACCESS.2019.2906402
31. Zander, K.K., Garnett, S.T., Ogie, R., Alazab, M., Nguyen, D.: Trends in bushfire related tweets during the Australian 'Black Summer' of 2019/20. For. Ecol. Manage. **545**, 121274 (2023). https://doi.org/10.1016/j.foreco.2023.121274
32. Shyrokykh, K., Girnyk, M., Dellmuth, L.: Short text classification with machine learning in the social sciences: the case of climate change on Twitter. PLoS ONE **18**(9), e0290762 (2023). https://doi.org/10.1371/journal.pone.0290762
33. Khalili, S., Breyer, C.: Review on 100% renewable energy system analyses-a bibliometric perspective. IEEE Access **10**, 125792–125834 (2022). https://doi.org/10.1109/ACCESS.2022.3221155
34. Umamaheswaran, S., Dar, V., Sharma, E., Kurian, J.S.: Mapping climate themes from 2008–2021-an analysis of business news using topic models. IEEE Access **11**, 26554–26565 (2023). https://doi.org/10.1109/ACCESS.2023.3256530
35. Saura, J.R., Ribeiro-Navarrete, S., Palacios-Marqués, D., Mardani, A.: Impact of extreme weather in production economics: extracting evidence from user-generated content. Int. J. Prod. Econ. **260**, 108861 (2023). https://doi.org/10.1016/j.ijpe.2023.108861

36. Zander, K., Nguyen, D., Mirbabaie, M., Garnett, S.: Aware but not prepared: understanding situational awareness during the century flood in Germany in 2021. Int. J. Disaster Risk Reduct. **96**, 103936 (2023). https://doi.org/10.1016/j.ijdrr.2023.103936
37. Kilanioti, I., Papadopoulos G.A.: A knowledge graph-based deep learning framework for efficient content similarity search of sustainable development goals data. Data Intell. **5**(3), 663–684 (2023). https://doi.org/10.1162/dint_a_00230
38. Purwandari, K., Cenggoro, T.W., Sigalingging, J.W.C., Pardamean, B.: Twitter-based classification for integrated source data of weather observations. IAES Int. J. Artif. Intell. **12**(1), 271 (2023)
39. Govindan, K.: How artificial intelligence drives sustainable frugal innovation: a multitheoretical perspective. IEEE Trans. Eng. Manage. **71**, 638–655 (2024). https://doi.org/10.1109/TEM.2021.3116187
40. Elavarasan, R.M., et al.: A comprehensive review on renewable energy development, challenges, and policies of leading indian states with an international perspective. IEEE Access **8**, 74432–74457 (2020). https://doi.org/10.1109/ACCESS.2020.2988011
41. Ramachandaramurthy, V.K., Ajmal, A.M., Kasinathan, P., Tan, K.M., Yong, J.Y., Vinoth, R.: Social acceptance and preference of EV users-a review. IEEE Access **11**, 11956–11972 (2023). https://doi.org/10.1109/ACCESS.2023.3241636
42. Xing, Z., Cao, X.: Promoting strategy of chinese green building industry: an evolutionary analysis based on the social network theory. IEEE Access **7**, 67213–67221 (2019). https://doi.org/10.1109/ACCESS.2019.2918028
43. Yuan, X.-M., Zheng, C.-C.: Evolutionary game and simulation analysis of low-carbon technology innovation with multi-agent participation. IEEE Access **10**, 11284–11295 (2022). https://doi.org/10.1109/ACCESS.2022.3143869
44. Yu, S.: An agent-based framework for policy simulation: modeling heterogeneous behaviors with modified sigmoid function and evolutionary training. IEEE Trans. Comput. Soc. Syst. **10**(4), 1901–1913 (2023). https://doi.org/10.1109/TCSS.2022.3196737
45. Wang, S., Liu, Q., Yuksel, S., Dincer, H.: Hesitant linguistic term sets-based hybrid analysis for renewable energy investments. IEEE Access **7**, 114223–114235 (2019). https://doi.org/10.1109/ACCESS.2019.2935427
46. Chapman, M., Xu, L., Lapeyrolerie M., Boettiger, C.: Bridging adaptive management and reinforcement learning for more robust decisions. Phil. Trans. R. Soc. B3782022019520220195 (2023). https://doi.org/10.1098/rstb.2022.0195
47. Srinivasan, S., Kumarasamy, S., Andreadakis, Z.E., Lind, P.G.: Artificial intelligence and mathematical models of power grids driven by renewable energy sources: a survey. Energies **16**(14), 5383 (2023). https://doi.org/10.3390/en16145383
48. Alyami, S.H.: Opportunities and challenges of embracing green city principles in Saudi Arabia future cities. IEEE Access **7**, 178584–178595 (2019). https://doi.org/10.1109/ACCESS.2019.2959026
49. Bucur, C., Tudorică, B.G., Oprea, S.-V., Nancu, D., Duşmănescu, D.M.: Insights into energy indicators analytics towards European green energy transition using statistics and self-organizing maps. IEEE Access **9**, 64427–64444 (2021). https://doi.org/10.1109/ACCESS.2021.3075175
50. Liu, Z., et al.: Research on intelligent decision of low carbon supply chain based on carbon tax constraints in human-driven edge computing. IEEE Access **8**, 48264–48273 (2020). https://doi.org/10.1109/ACCESS.2020.2978911
51. Francisco, M., Linnér, B.: AI and the governance of sustainable development. An idea analysis of the European Union, the United Nations, and the World Economic Forum. Environ. Sci. Policy **150**, 103590 (2023). https://doi.org/10.1016/j.envsci.2023.103590
52. Ferreira, J.J., Lopes, J.M., Gomes, S., Rammal, H.G.: Industry 4.0 implementation: environmental and social sustainability in manufacturing multinational enterprises. J. Clean. Prod. **404**, 136841 (2023). https://doi.org/10.1016/j.jclepro.2023.136841
53. Sarroeira, R., Henriques, J., Sousa, A.M., Ferreira da Silva, C., Nunes, N., Moro, S., Botelho, M.D.C.: Monitoring sensors for urban air quality: the case of the municipality of Lisbon. Sensors **23**(18), 7702 (2023). https://doi.org/10.3390/s23187702

54. Rolnick, D., Donti, P.L., Kaack, L.H., Kochanski, K., Lacoste, A., Sankaran, K., Ross, A.S., Milojevic-Dupont, N., Jaques, N., Waldman-Brown, A., Luccioni, A.S., Maharaj, T., Sherwin, E.D., Karthik Mukkavilli, S., Kording, K.P., Gomes, C.P., Ng, A.Y., Hassabis, D., Platt, J.C., Creutzig, F., Chayes, J., Bengio, Y: Tackling climate change with machine learning. ACM Comput. Surv. **55**(2), Article 42 (February 2023), 1–96 (2022). https://doi.org/10.1145/3485128
55. Tavoni, M.: Computational climate change: how data science and numerical models can help build good climate policies and practices. In: Bertoni, E., Fontana, M., Gabrielli, L., Signorelli, S., Vespe, M. (eds.) Handbook of Computational Social Science for Policy. Springer, Cham (2023). https://doi.org/10.1007/978-3-031-16624-2_14
56. Restrepo, N.J., Illari, L., Leahy, R., Sear, R.F., Lupu, Y., Johnson, N.F.: How social media machinery pulled mainstream parenting communities closer to extremes and their misinformation during Covid-19. IEEE Access **10**, 2330–2344 (2022). https://doi.org/10.1109/ACCESS.2021.3138982
57. Meddeb, P., Ruseti, S., Dascalu, M., Terian, S.-M., Travadel, S.: Counteracting French fake news on climate change using language models. Sustainability **14**(18), 11724 (2022). https://doi.org/10.3390/su141811724
58. Wang, Z., Huang, W.: A social media based approach for route planning during urban events. IEEE Access **8**, 207589–207598 (2020). https://doi.org/10.1109/ACCESS.2020.3037531
59. Kirimtat, A., Krejcar, O., Kertesz, A., Tasgetiren, M.F.: Future trends and current state of smart city concepts: a survey. IEEE Access **8**, 86448–86467 (2020). https://doi.org/10.1109/ACCESS.2020.2992441
60. Costa, E., Fontes, M., Bento, N.: Transformative business models for decarbonization: insights from prize-winning start-ups at the web summit. Sustainability **15**(18), 14007 (2023). https://doi.org/10.3390/su151814007
61. Yin, H., Wang, Z., Xu, Z.: Transmission mechanism and influencing factors of green behavior in dynamic multiplex networks. IEEE Access **9**, 104382–104394 (2021). https://doi.org/10.1109/ACCESS.2021.3099159
62. Wang, L., Wang, D.: Solving stance detection on tweets as multi-domain and multi-task text classification. IEEE Access **9**, 157780–157789 (2021). https://doi.org/10.1109/ACCESS.2021.3129468
63. Mooseder, A., Brantner, C., Zamith, R., Pfeffer, J.: (Social) media logics and visualizing climate change: 10 years of #climatechange images on Twitter. Soc. Media + Soc. **9**(1) (2023). https://doi.org/10.1177/20563051231164310
64. Hafdaoui, H.E., Khallaayoun, A.: Mathematical modeling of social assessment for alternative fuel vehicles. IEEE Access **11**, 59108–59132 (2023). https://doi.org/10.1109/ACCESS.2023.3284844
65. Prati, G., Tzankova, I., Albanesi, C., Cicognani, E.: Longitudinal predictors of perceived climate change importance and worry among Italian youths: a machine learning approach. Sustainability **14**(23), 15716 (2022). https://doi.org/10.3390/su142315716
66. Zhu, Z., Zhang, L.: Artificial intelligence empowers postgraduate education ecologically sustainable development model construction. Sustainability **15**(7), 6157 (2023). https://doi.org/10.3390/su15076157

Examining the Impact of COVID-19 on Private Healthcare Providers: Elective Procedure Volumes and Consequences

Michal P. Przewlocki and Zuzana Stolicna

Abstract This global paper examines the impact of the COVID-19 pandemic on elective surgeries and surgical departments globally. It highlights the need to analyze the challenges faced by the healthcare sector in addressing evolving healthcare demands and resource allocation, focusing on enhancing preparedness and addressing vulnerabilities. The paper also emphasizes the role of the private sector in complementing public healthcare during the pandemic. The study reviews studies published worldwide, mainly in Austria, Belgium, the United Kingdom, and the United States. In Austria, the reduction in surgical interventions during the second wave was less severe compared to the first wave, despite higher infection rates and ICU admissions. In Belgium, there was a significant decrease in elective knee surgeries and outpatient visits during the lockdown period. In the United States, hospitals lost approximately between US$1430 and US$1700 an hour for same-day surgery. Globally, an estimated 28.4 million elective operations were canceled or postponed during the 12-week peak of the pandemic. The economic impact of these cancellations underscores the importance of careful planning and strategies to address the backlog of surgeries after the pandemic.

Keywords COVID-19 · Private healthcare providers · Elective procedure volumes · Consequences · Impact · Healthcare systems · Global impact · Challenges

M. P. Przewlocki · Z. Stolicna (✉)
Faculty of Management, Comenius University, Bratislava, Slovakia
e-mail: zuzana.stolicna@fm.uniba.sk

M. P. Przewlocki
e-mail: przewlocki3@uniba.sk

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2024

P. Štarchoň et al. (eds.), *Data-Centric Business and Applications*, Lecture Notes on Data Engineering and Communications Technologies 213,
https://doi.org/10.1007/978-3-031-62213-7_19

1 Introduction

1.1 Background and Context of the COVID-19 Pandemic's Impact on Healthcare Systems

The global health crisis of the COVID-19 pandemic, initiated by the novel coronavirus SARS-CoV-2, has exerted widespread impacts on healthcare systems worldwide [1, 2]. It emerged in late 2019 in Wuhan, China, and quickly spread internationally. On March 2020, it was announced by World Health Organization [3] a pandemic as the virus rapidly infected people across continents. This pandemic has presented an unprecedented and distinct challenge, reminiscent of the Spanish flu pandemic of the early twentieth century. As a response, various public health policies were developed, and governments issued a multitude of recommendations to curb transmission [4]. Some of these measures involve mandatory use of personal protective equipment (PPE such as KN95 masks, goggles, and gowns), social distancing, contact tracing, and regular testing for healthcare workers.

According to Bernacki et al. [2], the effects of COVID-19 were evident across various stages of care within the "universal" care pathway. One of the most significant impacts of the pandemic on healthcare systems was the potential for overwhelming medical infrastructure. This health challenge has led to a fundamental shift in the priorities of medical and surgical procedures, prompting numerous healthcare systems to suspend their customary screenings and routine services. The focus shifted to managing and treating COVID-19 patients, potentially disrupting routine medical care for other conditions [5]. It is important to mention that the pandemic's impact on mental health became a significant concern [6]. These psychological effects undermine and debilitate healthcare professionals who, due to suboptimal working conditions, face heightened risks of exposure.

Furthermore, experts in the realm of economics are delving into an investigation to ascertain whether this pandemic is an extraordinary event or if it signifies an increased probability of future pandemics within our globally interconnected environment. The development, distribution, and administration of COVID-19 vaccines posed additional challenges for healthcare systems, associated with timely administration, high costs, and efficient tracking of doses. Healthcare systems encountered financial strain due to escalated costs related to medical equipment, workforce, and improvements in infrastructure aimed at handling the pandemic. Ongoing studies have examined the economic transformations and resource allocation necessary to address the evolving healthcare demands, healthcare workforce needs, and fluctuations in material costs.

1.2 Aims of This Review

As the pandemic emerged, there was a widespread suspension of "elective" surgeries to curb virus transmission and allocate resources effectively. However, this temporary

halt had significant consequences, shedding light on the essential nature of these procedures [7].

To our knowledge, there are few reports published in this field, mainly in Europe. The main purpose is to assess the potential shifts and difficulties that will confront the healthcare industry in the forthcoming decades. This will aid both private and public entities in pinpointing key areas that demand focus and financial readiness to alleviate the repercussions of future pandemics. The background and context of the COVID-19 pandemic's impact on healthcare systems reflect a complex interplay of challenges, adaptations, and changes. In this line, we aim to investigate the volatility of these new challenges and assess the allocation of funds, considering whether the focus should be on enhancing overall preparedness or addressing specific vulnerabilities exposed by the current pandemic.

One of the sections of this paper focuses on the analysis of shifts in demand for elective surgeries and the ongoing need for research and discussion in this domain. The ultimate goal is to provide a foundation for the development of tools and frameworks that can support small and medium-sized private healthcare providers in contributing to public sector goals, particularly in improving the availability of essential services and infrastructure for pandemic preparedness. The implementation of a private care framework can help manage sudden increases in demand and other fluctuations that public hospitals may encounter. The COVID-19 pandemic has highlighted the essential role of the private sector in complementing public healthcare by providing crucial infrastructure, such as testing facilities, to alleviate the strain on overwhelmed public healthcare services. This framework has proven invaluable in relieving the burden on overburdened public hospitals and addressing the unmet demand for elective surgeries and preventative care, which were often deprioritized during the peak of the pandemic.

This topic is considered of great importance for small practices, clinics, polyclinics, and highly specialized medical centers that receive funding from public sources or the private sector, including private health insurance providers.

In this line, we will focus on specific countries to understand the dynamic of increases and decreases in elective procedures, mainly from Austria, Belgium, the United Kingdom, and the United States. The objectives of this review encompass investigating the repercussions of COVID-19 on private healthcare providers, specifically focusing on the impact on elective procedure volumes and the resulting consequences of this pandemic. Economic losses and interesting data published regarding this field will be explained in detail in the next sections.

2 Importance of Elective Surgeries and Their Role in Healthcare

Elective surgical interventions refer to those procedures that are scheduled in advance, distinct from those necessitated by emergent and life-threatening conditions [8, 9]. It's important to clarify that "elective" does not mean that these surgeries are merely optional or with reduced clinical importance. Instead, they are defined by the flexibility in their timing, not by their medical significance.

To our knowledge, elective surgeries present a lot of benefits. These procedures are typically performed to improve a patient's quality of life, address chronic conditions and relieve pain. Procedures like joint replacements, cataract removals, and cosmetic surgeries can significantly improve patients' well-being. They present also an important role in disease prevention (for example, prophylactic mastectomy for individuals at a heightened risk of breast cancer).

The scope of elective surgeries covers a wide range of medical fields, as follows:

- **Ophthalmological Procedures**: An example is cataract extractions, which aim to correct vision impairments.
- **Orthopedic Interventions**: This includes joint replacement surgeries, like hip or knee replacements, often sought by patients with deteriorative joint conditions to regain function and alleviate discomfort [10].
- **General Surgical Procedures**: Among these are hernia repairs, designed to correct physiological abnormalities even if they aren't posing an immediate threat [8, 9].
- **Otolaryngological Surgeries**: Procedures such as tonsillectomies can be essential for treating recurrent infections or breathing obstructions—a common pediatric procedure.
- **Cosmetic and Reconstructive Surgeries**: Surgeries such as rhinoplasty or breast augmentation. While sometimes viewed as elective, they can significantly affect a patient's well-being, both physically and psychologically.

The term "elective" should not be misconstrued as a commentary on the importance or influence of the procedure on an individual's overarching health trajectory [4]. Rather, it references the ability to strategically manage the timing of the procedure, harmonizing the patient's clinical requirements with logistical factors. Usually, the resolution to advance with an elective surgical intervention emerges after thorough consultations between the patient and the attending physician, requiring a deep understanding of the procedure's risks and benefits.

2.1 Their Role in Healthcare Providers' Financial Stability

To our knowledge, elective surgery cancellation is considered a fundamental problem in health care services. Selective surgeries play a crucial role in the financial stability

of healthcare providers. According to Koushan et al. [11], "it causes considerable disruption to patient flow, further eroding often already stretched operating capacity, and consequentially reduces both hospital performance and patient satisfaction."

Moreover, elective surgeries contribute to better efficiency and cost-effectiveness as they can optimize resource utilization, including operating rooms, medical staff, and equipment. Elective procedures frequently yield significant income, playing a crucial role in upholding hospital operations, supporting staff retention, and facilitating investments in medical advancements and infrastructure development.

To our knowledge, American Hospital Association [12] analyzed and aimed to quantify the financial impact of COVID-19 on American Hospital systems, comparing with data from Medicare inpatient and outpatient claims files and the AHA Annual Survey Database (2018). The data analyzed showed the scope of the financial burden that the hospital systems had to endure between March and June 2020. The net financial impact of COVID-19 hospitalizations was estimated at $36.6 billion over the four months. The AHA [13] also estimates that due to the COVID-19 pandemic, non-federal hospitals were expected to lose about $161 billion of revenue over the measured period, or over $40 billion per month. This number included "canceled surgeries, various levels of canceled non-elective surgeries and outpatient treatment, and reduced emergency department services."

The report also calculated in-direct costs that were significant such as Personal Protective Equipment (PPE) and healthcare support for front-line workers. The costs of personal protection equipment were calculated at $600 million per month. Front-line workers were provided with additional support such as childcare, medical screening, and COVID-19 treatment. The additional support costs were significant, amounting to $550 million per month [13].

According to this Association, these costs might not show the full picture. Due to limitations of data that AHA had publicly available, some costs weren't included [13]. We considered the following four aspects:

1. Drug shortage costs
2. Wage labour costs
3. Non-PPE medical supplies and Equipment costs
4. Capital costs.

3 Austria's Case: Influence of the Pandemic on Elective Surgery Activity

The impact of COVID-19 on elective surgery during the second wave in the fall and winter of 2020/2021 was examined by Gasteiger et al. [9] based on data from a tertiary university hospital in Austria. This study examined surgery statistics during the second wave of the pandemic in comparison to the same period over the last five years. Additionally, it compared the decrease in surgical procedures during the second wave to the decrease seen in the first wave in spring 2020.

According to the same authors, the findings showed higher 7-day incidence of COVID-19 infections and a higher number of patients needing Intensive Care Unit (ICU) treatment during the second wave. Interestingly, surgical interventions only decreased by a modest 3.22% during the second wave, contrasting sharply with the significant drop of 65.29% witnessed during the initial outbreak. During the first wave, elective surgical interventions plummeted by an alarming 88.63%, but this reduction was a mere 1.79% in the subsequent wave. Likewise, the downturn in emergency and oncological procedures was quite pronounced during the first wave, registering at 35.17% and 47.59%, respectively. Yet, during the second wave, these numbers tapered to 5.15% and 3.89%, respectively.

The study suggests that the reduction in surgical activity was less pronounced despite the higher occupancy of ICU beds. The authors speculate that a better understanding of the disease, adequate supply of disposables, and improved interdisciplinary management of surgical and ICU resources may have contributed to this improvement.

To our knowledge, the decline in elective surgeries resulted in financial challenges for healthcare providers, including reduced revenues from these procedures.

4 Belgium's Case: Elective Surgeries and Patient Visits

A recent study performed by Tan et al. [14] aimed to provide the orthopedic community with insights into the recovery of elective care in Europe. The researchers conducted surveys among members of the Belgian Knee Society (BKS) to evaluate the resumption of elective surgeries and outpatient visits in the first six months after the initial COVID-19 lockdown. The study also assessed the implementation of the ESSKA COVID-19 Guidelines and Recommendations for Resuming Elective Surgery among Belgian knee surgeons.

During the seven-week lockdown period, there was a drastic decrease in elective knee surgeries, with a 97% reduction compared to the same period in the previous year (Fig. 1). Outpatient visits also decreased by 91% during this time. Video consultations were utilized by 93% of participants to maintain patient care.

Upon the restart of elective care, the availability of operating room (OR) time remained limited, with only 14% of participants having full access to OR time after four weeks (Fig. 1). The mean number of elective surgical procedures during the first month after the restart decreased by 33% compared to pre-COVID-19 levels. Additionally, waiting times for surgery increased for almost 60% of participants, primarily due to a lack of operating room personnel, hospital beds, and general resources. Outpatient clinic visits gradually increased after the resumption of care, reaching 81% of pre-COVID-19 levels after four weeks. However, 59% of participants reported a decrease in demand for outpatient visits compared to pre-pandemic times. The use of video consultations decreased over time, with 41% of participants no longer utilizing them after one month.

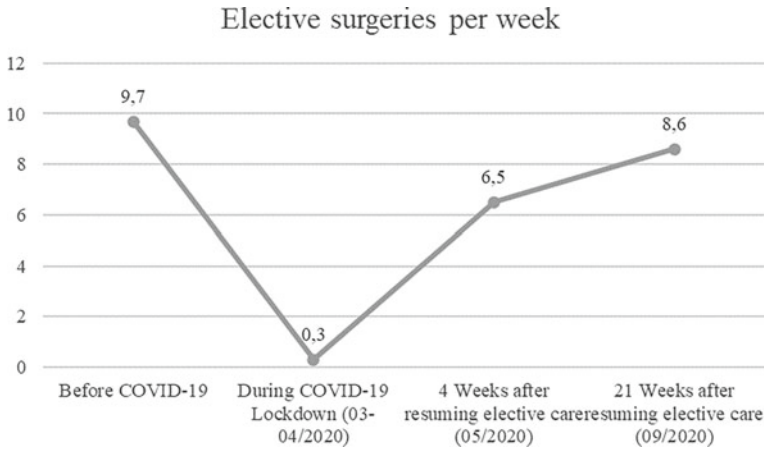


Fig. 1 Elective knee surgeries per week based on Tan et al. [14] research

At 21 weeks after the restart of elective care, the mean number of surgeries performed had recovered to 89% of pre-pandemic levels, indicating a gradual improvement (Fig. 1). However, it should be noted that not all surgeons experienced a decrease in surgical procedures, with 7% of surgeons reporting an increase.

This study highlighted the substantial decrease in elective orthopedic surgeries and outpatient visits during the COVID-19 lockdown in Europe. It underscores the challenges faced by orthopedic departments in resuming care and implementing guidelines.

5 Global Overviews of Elective Surgeries: Data, Cancelation, and Impacts

To our knowledge, different studies were published worldwide related to this field. After the COVID appearance, different guidelines were proposed reinforcing the widespread cancellation of elective surgeries worldwide [13, 15]. The global elective surgery schedules have been heavily disrupted by the COVID-19 pandemic. Many countries have taken the step of deferring or canceling elective procedures to conserve resources, curb the spread of the virus, and effectively manage hospital capacities. As a result, redistribution of resources, adjustments in the workforce, and changes in capacity to meet pandemic-related requirements were some of the implications for healthcare systems.

According to De et al. [16], it is estimated that approximately 28,404,603 elective surgeries for adults were postponed during the 12-week peak period, globally. This translates to an average of about 2,367,050 surgeries being delayed each week, with over 2 million cases affected weekly.

During the COVID-19 pandemic, hospitals worldwide experienced significant disruptions, leading to the cancellation of elective surgeries [5]. A study conducted by Collaborative [17] focused on estimating the volume of these canceled operations and their economic impact. Researchers employed a Bayesian β-regression model, along with surgical case mix data and country-specific surgical volume estimates, to estimate cancellation rates for 190 countries.

The study revealed that approximately 28.4 million elective operations were canceled or postponed globally during the peak 12 weeks of the pandemic [17]. This corresponded to a weekly cancellation rate of around 2.4 million operations. Most cancellations (90.2%) were for benign conditions, followed by cancer surgeries (8.2%) and obstetric procedures (1.6%). These cancellations had a significant economic impact, with potential long-term consequences for population health, productivity, and society.

Understanding the volume of canceled operations and their economic impact is vital for healthcare systems to plan for post-pandemic surgical recovery effectively. The study emphasizes the need for careful planning and strategies to address the backlog of canceled surgeries once the pandemic subsides. Failure to address this backlog may result in negative health outcomes, reduced quality of life, unnecessary deaths, and significant economic burdens.

The findings of this study provide valuable insights for decision-making and resource allocation in mitigating the consequences of disrupted surgical services caused by the COVID-19 pandemic [17]. The Bayesian β-regression model serves as a robust tool for estimating cancellation rates and can contribute to future planning efforts in healthcare systems worldwide.

On the other hand, we can consider Hong Kong's situation. According to Wong and Cheung [10]'s research, a comparison was performed between patients treated in the early stages of the COVID-19 pandemic (January 25 to March 27, 2020) and a control group over the previous four years. Importantly, this is the first quantitative study of the impact of COVID-19 on orthopedic services. In this research, 43 public hospitals and 122 outpatient clinics in Hong Kong were analyzed, covering a population of 7.5 million residents. The analysis encompassed a total of 928,278 patient episodes, including data on operations, hospital admissions, and outpatient clinic visits. Orthopedic operations experienced a significant decline of 44.2%, with a shift in the ratio of emergency to elective procedures. Procedures related to fractures and joint replacements exhibited reductions ranging from 20 to 84%. However, surgeries for orthopedic infections remained stable. Hospitalizations decreased by 41.2%, and clinical outpatient visits decreased by 29.4%. Despite these reductions, patients did not face longer wait times for emergency operations and consultations. The findings underscored the ongoing demand for orthopedic care despite substantial reductions in various metrics during the pandemic, emphasizing the need for strategic resource allocation and staffing considerations by healthcare professionals.

To our knowledge, physician well-being is the cornerstone of every well-functioning health system because it "improves the quality of patient care, increases patient satisfaction, and decreases medical errors" [4]. The mental health of healthcare professionals was affected during the pandemic, specifically in China, based

on intense psychological experiences, traumatization, and various mental health disorders among healthcare workers.

To our knowledge, in Brazil, the elective surgical backlog surpassed 900,000 cases by December 2020 [18]. Considering Europe's situation, various European countries implemented measures to curb the spread of the virus, including postponing or canceling non-urgent medical procedures. These cancellations aimed to allocate resources, including healthcare staff and facilities, to manage the influx of COVID-19 patients. The prevalence of these cancelations depends on the country and hospital. Consequently, it has highlighted significant gaps such as limited resources in public health, outdated technology, and data sharing challenges [19].

6 United Kingdom's Case: Elective Surgeries Cancellations and Impact

Regarding the UK, this country has the greatest death toll in Europe and is third in the world after the United States and Brazil [20]. Moreover, a prospective observational study was conducted by De et al. [16], focusing on adult patients who underwent elective surgeries in a COVID-free setting. The research encompassed 303 participants, categorized based on anesthesia type, surgical specialties, and the American Society of Anesthesiologist Grade. Impressively, 96% of patients were discharged on the same day, and the compliance rate for pre-operative COVID-19 testing was 100%. Notably, there were no instances of mortality or significant respiratory complications within the 30-day post-operative period. In conclusion, by carefully selecting patients, involving pre-assessment and anesthesia teams concurrently, and adhering strictly to pre-operative protocols, it is possible to offer secure elective surgical services under reasonably controlled community transmission [16]. Additionally, ensuring meticulous post-operative care to address potential COVID-19 infections is of paramount importance to uphold safety standards. Nevertheless, maintaining a COVID-free and secure environment is especially critical for the success of these elective procedures.

According to an interesting study performed by Dobbs et al. [21], the number of canceled surgical procedures in England and Wales during the COVID-19 pandemic is at least 2.4 million by the end of 2021, which represents more than 6 months of normal surgical activity.

7 United States' Case: Economic Impacts on Healthcare Providers

Focusing on the US, "the estimated total annual cost of elective inpatient and outpatient surgical procedures was $147.2 billion, and estimated total hospital reimbursement was $195.4 to $212.2 billion" [8]. Moreover, "cancellation of all elective procedures would result in estimated losses of $16.3 to $17.7 billion per month in revenue and $4 to $5.4 billion per month in net income to US hospitals".

According to Meredith et al. [7], the economic stability of the healthcare system represents around 20% of the US economy. Delayed screenings and treatments have been reported, with potential long-term effects on survival rates for conditions like breast and colorectal cancer.

Furthermore, up to 71.8% of live donor kidney transplants were completely suspended [4]. Tonna et al. [22] mentioned that elective cases related to musculoskeletal, circulatory, and digestive systems make up 33% (amounting to $447 billion) of the total revenue in the US. According to the same authors, if all elective surgeries are canceled, the excessive load on ICUs would decrease from 160 to 130%. In order to manage capacity after the pandemic, most hospitals choose to postpone elective surgeries.

An article published by Mazzaferro et al. [23] explores the financial impact of halting elective surgeries, the immediate period after resuming surgeries, and the effects of continuing surgeries during the second wave of the pandemic. The study focuses on the Department of Surgery at a large academic institution, analyzing real-world financial data to understand the consequences of the COVID-19 pandemic on surgical departments.

The study examined financial data from the Department of Surgery and additional surgical departments at the University of Pennsylvania Health System (UPHS) during the pandemic [23]. Revenue and work relative value units (wRVUs) were compared between the first and second wave of COVID-19 cases and the corresponding periods from the previous year. Hospital census decay rates were calculated to assess the decline in cases during each wave.

The results revealed significant revenue losses across all surgical departments during the first wave, with the department of surgery experiencing the greatest net revenue loss. Comparing 2020 to 2019 over five months, the health system's net revenue loss amounted to $99,674,376 accounting for 42% of the total revenue loss during that time.

Specifically, the Department of Surgery suffered a net revenue loss of $58,368,951, representing 25% of the health system's total loss. Following the department of surgery, orthopedic surgery, neurosurgery, otorhinolaryngology, and oral maxillofacial surgery also experienced substantial revenue declines. Analyzing the revenue loss further, a significant difference was found between the first and second waves. During the first wave, the median net revenue loss per month per division was higher compared to the second wave. Similarly, the percent change in revenue during the first

wave was greater than during the second wave when compared to the corresponding months from the previous year [23].

The comparison of revenue between the two years revealed a significant decrease in net revenue during the first wave. However, there was no significant difference in net revenue between corresponding months during the second wave. Notably, the months directly impacted by the elective surgery shutdown, namely March, April, and May, experienced a significant decrease in net revenue during the first wave. In contrast, subsequent months of the first wave and all months of the second wave did not exhibit significant differences. Additionally, the study examined the changes in wRVUs during the two waves. A significant difference was observed in the change between the first and second waves compared to the corresponding month from the previous year. The first wave experienced a larger drop in wRVUs and a greater percentage decrease compared to the second wave [23].

These findings underscore the substantial financial impact of the pandemic on surgical departments, with significant revenue losses and reductions in wRVUs during the first wave. The slower recovery and smaller revenue decline observed in the second wave highlight the need for effective management strategies to mitigate the financial implications faced by healthcare institutions.

Moreover, Khullar et al. [24] also identified numerous financial challenges that are faced by healthcare providers in the United States. Due to the rapid increase in COVID-19 patients, hospitals faced a strain on their capacity, Consequently, they had to close outpatient departments and postpone elective visits as well as surgery procedures. However, these changes pose a threat to hospitals' financial viability, especially for those already facing financial difficulties and relying heavily on revenue from outpatient and elective services [24].

Elective procedures, particularly orthopedic and cardiac surgeries, are highly profitable for hospitals, and the closure of these services leads to a significant loss in revenue. While increased hospital occupancy due to COVID-19 patients and a potential surge in services after the pandemic might partially offset the losses, it may not be sufficient or evenly distributed among hospitals. Hospitals in some regions will experience increased revenue but also face higher costs for additional staff and resources, while others will mainly suffer from lost revenue due to restrictions on nonessential services [24].

These authors explained that since 2018 many hospitals have limited liquid assets and are not prepared to handle substantial financial shocks while responding to the pandemic. The financial position of hospitals varies, with larger hospital systems generally having positive operating margins, while smaller and rural hospitals face significant financial challenges. The COVID-19 pandemic exacerbates these financial difficulties, and one in five rural hospitals is at risk of closure due to financial problems. Hospitals with lower financial liquidity are often small, rural, and have lower occupancy rates, and critical access status. On the other hand, those with higher liquidity are more likely to be nonprofit hospitals, teaching hospitals, or affiliated with health systems.

The article recommended lump-sum payments to help hospitals prepare for and respond to COVID-19 surges, funds to offset losses from reduced revenue, and state

governments allocating funds based on local assessments of financial consequences [24].

Interestingly, in regions like Louisiana, Michigan, San Francisco, and Virginia, disparities are evident, with higher death rates and infection rates among communities of color [25]. These data can be explained by the presence of pre-existing conditions which amplify the susceptibility to COVID-19 (such as hypertension, diabetes, and obesity). These authors considered that limited access to healthy lifestyles and healthcare affects communities of color representing another aspect to take in mind.

7.1 US Hospitals and Their Ability to Adapt

Financially, hospitals have suffered significant losses, resorting to cost-shifting practices to cope in the US [7].

A recent research published by Mattingly et al. [26] analyzed the COVID-19 elective surgery problem from a different viewpoint. The authors mention that the United States lacked a framework, systems, or protocols to address an abrupt reduction in surgical procedure volume. However, just 35 days after the American College of Surgeons (ACS) advised reducing elective procedures, a collaborative statement was issued by the American Society of Anesthesiologists, the Association of preoperative Registered Nurses, and the American Hospital Association. This statement offered guidance for the resumption of elective surgical procedures. Hospitals took steps to reopen access to elective surgical procedures.

For instance, in Veterans Affairs hospitals, surgical procedures across various specialties rebounded between May and June 2020, although not reaching the previous year's levels. As the volume of COVID-19 patients surged during the subsequent months, known as the second wave, the regulation of surgical procedure scheduling was delegated to states and individual hospital systems [26].

According to the same research, drawing from a comprehensive collection of surgeries across 3498 Current Procedural Terminology (CPT) codes, the study compares surgical trends from 2019 until the first month of 2021. The aim is to capture the immediate aftermath of the pandemic's onset and its continued repercussions into the following year. A broader analysis provides a sense of scale: in 2019, the U.S. saw 6,651,921 surgeries in total. However, by 2020, this number had plunged to 5,973,573, with January 2021 further registering 483,073 surgeries. The sharp descent, amounting to 678,348 fewer surgeries in 2020, translated to a 10.2% dip, giving a stark indication of the disruptions caused.

Contrary to popular misconceptions, the term 'elective' does not necessarily denote surgeries that are optional or unnecessary. Instead, it typically refers to planned surgeries that aren't emergencies, allowing for a certain degree of flexibility regarding their scheduling. Given the pressing demands of the pandemic, many medical facilities opted to either postpone or cancel these elective procedures to conserve resources, a strategy evident in the drop in numbers. The beginning of 2020, marking the initial pandemic shutdown, saw surgeries plummeting by 48.0% compared to the same

period in 2019. Within this decline, elective surgeries bore a significant brunt of the reductions. Cataract surgeries, primarily elective, decreased by a staggering 89.5%. Similarly, elective ENT procedures were down by 70.1%. Musculoskeletal surgeries, often consisting of treatments like knee and hip replacements, which are commonly elective, witnessed a 63.7% reduction [26].

Elaborating on specific elective procedures provides a clearer picture. Cataract repair, a surgery that often falls under the elective category due to its nature, experienced a precipitous 89.5% drop during the initial shutdown. Bariatric surgery, a treatment option for obesity, fell by 90.8%. Knee arthroplasty and hip arthroplasty, common procedures for osteoarthritis patients, were reduced by 86.8% and 79.9%, respectively. These figures emphasize how elective surgical treatments, despite their significance to patient well-being, were substantially affected during the pandemic. These deferrals weren't made lightly; they stemmed from a combined effort to optimize available medical resources to combat an overwhelming and then-little-understood viral threat [26].

Nevertheless, the latter months of 2020 witnessed a subsequent rise in COVID-19 cases, leading to a resurgence in elective surgeries [8, 25]. While surgical numbers neared those of 2019, some elective procedures like knee arthroplasty and certain abdominal repairs still lagged. An interesting observation during this period was the blurring relationship between COVID-19 incidence rates and elective surgery volumes. In the initial shutdown, higher rates directly correlated with reduced surgeries. Yet, as the pandemic wore on, many states showcased an ability to conduct near-normal or even higher rates of elective surgeries despite the looming presence of the virus.

The elasticity displayed by the healthcare sector in resuming elective surgical treatments highlights its inherent adaptability. However, there's an underlying concern regarding the postponed or canceled procedures from earlier in the year. While the study illuminates the magnitude of the decline, it does not investigate deeply the subsequent health ramifications for those who had their elective surgeries delayed. In this line, it's imperative to reevaluate the true costs of care, implement robust testing protocols, and foster a sense of shared responsibility to ensure the continuation of nonemergency surgeries while navigating the complexities of the COVID-19 era [7].

8 Economic Consequences and Strategies

As a result of the COVID-19 pandemic, there has been the emergence of challenges like a surgical backlog due to postponed procedures and financial pressures on healthcare institutions.

The cancellation of elective procedures during the coronavirus disease pandemic has had a substantial economic impact on the worldwide hospital system [15]. For example, only in US hospitals, do elective procedures account for approximately $195.4 to $212.2 billion in revenue and $48.0 to $64.8 billion in net income per

year [8]. Moreover, Koushan et al. [11] mentioned that US hospitals lose between US$1430 and US$1700 an hour for same-day surgery, approximately.

In this line, hospitals have postponed and canceled elective surgeries. The reasons behind surgery cancellations can vary across hospitals. The main aim was a substantial increase in hospital, resources, and ICU bed capacity, though this will vary between states, and at significant financial cost. This organization was adjusted according to simulated trends of COVID-19 incidence [22]. Elective inpatient surgeries account for 27% of hospital and ICU beds and 43% of gross revenue, which varies substantially by specialty. The most postponing elective surgeries (33%) were related to procedures involving the musculoskeletal, cardiovascular, and digestive systems.

However, other factors such as the unavailability of operation room time or inappropriate scheduling policies could be considered [11]. According to the same authors, patient-related causes, such as patient absence and patient refusal, also contribute to cancellations, although in less prevalence.

It is important to note that the effects are not only economic ones but also on both hospital performance and patient contentment. It is a fundamental challenge within healthcare systems, resulting in significant disruptions to patient pathways. Additionally, cancellation creates psychological and financial hardships for patients and families as their daily life is disrupted [11]. Moreover, the mental health of healthcare professionals was affected during the pandemic [4].

As we mentioned previously, these substantial reductions in elective procedure volumes result in several significant observations. These financial pressures arise from a decrease in income, heightened expenses, and difficulties in upholding operational viability.

In this line, adaptive strategies are required in the healthcare field, ensuring the continuation of quality patient care while addressing the economic challenges posed by the pandemic. The pandemic has spurred innovative changes in the realm of elective surgeries. For example, the adoption of regular virtual healthcare practices is a positive effect on this field [5]. Telemedicine, virtual consultations, and remote pre-operative assessments have surfaced as alternatives for conventional procedures, reducing direct physical interactions, and enhancing the efficient use of resources. Moreover, a holistic approach is imperative for financial stability, optimizing resource allocation, and fostering innovation in healthcare service delivery.

9 Conclusions

In summary, elective procedures hold immense significance for the financial health of healthcare providers for several compelling reasons. The observations drawn from the analyzed studies underscore the aftermath of the COVID-19 pandemic on elective surgeries and the subsequent financial implications for healthcare systems. As previously noted, there are various compelling arguments favoring a deeper exploration of the advantages of elective healthcare for healthcare providers globally.

Firstly, Revenue Generation stands out as a critical factor. Elective surgeries make substantial contributions to the revenue streams of healthcare providers. The reduction or elimination of these procedures during the pandemic led to significant revenue shortfalls in surgical departments.

Moreover, Cost Coverage is pivotal. Elective surgeries often yield higher profit margins, allowing healthcare providers to offset fixed costs such as salaries, facility maintenance, and administrative expenditures. This financial buffer supports the stability of healthcare institutions by generating revenue that can be allocated to essential resources for maintaining quality care.

Equally important is the role of Elective Surgeries in balancing healthcare services. While prioritizing emergency and essential care remains paramount, elective surgeries play a complementary role in achieving a comprehensive healthcare ecosystem. Conducting such surgeries not only generates supplementary revenue but also subsidizes essential services that might not be financially self-sustaining.

The perspective of Infrastructure and Resource Utilization is also notable. Executing elective surgeries often necessitates specialized infrastructure, like operating rooms and surgical equipment. By optimizing these resources through elective surgeries, healthcare providers can maximize efficiency and returns on investment, bolstering the financial sustainability of healthcare operations.

Lastly, Elective Surgeries contribute to Economic Recovery and Growth. Sound financial standing empowers healthcare providers to contribute to economic expansion through job creation, technological investments, and support for various sectors. The resurgence of elective surgeries post the pandemic is pivotal in recovery strategies, restoring financial stability and fostering overall economic well-being within different regions.

As we mentioned, the COVID-19 pandemic had a lot of consequences on private healthcare providers, not only economic losses but also changes in psychological consequences. Both patients and professionals were affected. The study focused on substantial reductions in elective procedure volumes and highlights several significant observations. This research offers valuable perspectives on how the pandemic has influenced surgical operations, including cancellations and financial consequences. New strategies must be implemented in order to control this situation for future pandemics. As the pandemic continues to exert its influence, the findings emphasize the importance of resilience, flexibility, and collaborative efforts among private healthcare providers to mitigate the adverse effects and navigate the path to recovery. Effective planning, resource allocation, and management strategies are crucial for mitigating the consequences of disrupted surgical services caused by the pandemic.

In light of the COVID-19 pandemic, the narrative surrounding “elective” surgery has evolved, underscoring its indispensable role in the healthcare ecosystem.

References

1. Sabetkish, N., Rahmani, A.: The overall impact of COVID-19 on healthcare during the pandemic: a multidisciplinary point of view **4**(4), e386 (2021)
2. Bernacki, K., Keister, A., Sapiro, N., Joo, J.S., Mattle, L.: Impact of COVID-19 on patient and healthcare professional attitudes, beliefs, and behaviors toward the healthcare system and on the dynamics of the healthcare pathway. BMC Health Serv. Res. **21**(1), 1309 (2021)
3. WHO: Novel Coronavirus (2019-nCoV): situation report, 11 (2020)
4. Mehta, A., Awuah, W.A., Ng, J.C., Kundu, M., Yarlagadda, R., Sen, M., et al.: Elective surgeries during and after the COVID-19 pandemic: case burden and physician shortage concerns. Ann. Med. Surg. **81**, 104395 (2022)
5. Myers, L.C., Liu, V.X.: The COVID-19 pandemic strikes again and again and again. JAMA Netw. Open **5**(3), e221760-e (2022)
6. Boluarte Carbajal, A., Sánchez Boluarte, A., Rodríguez Boluarte, A., Merino, S.C.: Working conditions and emotional impact in healthcare workers during COVID-19 pandemic. J. Healthc. Qual. Res. **35**(6), 401–402 (2020)
7. Meredith, J.W., High, K.P., Freischlag, J.A.: Preserving elective surgeries in the COVID-19 pandemic and the future. JAMA **324**(17), 1725–1726 (2020)
8. Best, M.J., McFarland, E.G., Anderson, G.F., Srikumaran, U.: The likely economic impact of fewer elective surgical procedures on US hospitals during the COVID-19 pandemic. Surgery **168**(5), 962–967 (2020)
9. Gasteiger, L., Abram, J., Klein, S., Tscholl, P., Hell, T., Putzer, G., et al.: Impact of COVID-19 on elective, emergency and oncological surgery during the first and the second wave in a tertiary university hospital. Wien. Klin. Wochenschr. **134**(23), 868–874 (2022)
10. Wong, J.S.H., Cheung, K.M.C.: Impact of COVID-19 on orthopaedic and trauma service: an epidemiological study. J. Bone Joint Surg. Am. **102**(14), e80 (2020)
11. Koushan, M., Wood, L.C., Greatbanks, R.: Evaluating factors associated with the cancellation and delay of elective surgical procedures: a systematic review. Int. J. Qual. Health Care **33**(2) (2021)
12. AHA: Hospitals and Health Systems Face Unprecedented Financial Pressures Due to COVID-19 2020. https://www.aha.org/system/files/media/file/2020/05/aha-covid19-financial-impact-0520-FINAL.pdf
13. AHA: Financial Implications of COVID-19 on Hospitals and Health Systems 2020. https://www.aha.org/issue-landing-page/2020-09-17-financial-implications-covid-19-hospitals-and-health-systems
14. Tan, Y.N., Vandekerckhove, P.J., Verdonk, P.: The long road to recovery: at six months since the first COVID-19 wave, elective orthopedic care has still not fully recovered in Belgium. J. Exp. Orthop. **7**(1), 99 (2020)
15. Barnett, M.L., Mehrotra, A., Landon, B.E.: Covid-19 and the upcoming financial crisis in health care **1**(2) (2020)
16. De, C., Shah, S., Suleiman, K., Chen, Z., Paringe, V., Prakash, D.: Safe elective surgical practice during COVID-19 pandemic—a prospective observational study of 303 elective surgeries in the UK. Cureus **13**(8), e16984 (2021)
17. Collaborative, C.: Elective surgery cancellations due to the COVID-19 pandemic: global predictive modelling to inform Surgical Recovery Plans. Br. J. Surg. **107**(11), 1440–1449 (2020)
18. Truche, P., Campos, L.N., Marrazzo, E.B., Rangel, A.G., Bernardino, R., Bowder, A.N., et al.: Association between government policy and delays in emergent and elective surgical care during the COVID-19 pandemic in Brazil: a modeling study. Lancet Reg. Health Am. **3**, 100056 (2021)
19. Negro-Calduch, E., Azzopardi-Muscat, N., Nitzan, D., Pebody, R., Jorgensen, P., Novillo-Ortiz, D.: Health information systems in the COVID-19 pandemic: a short survey of experiences and lessons learned from the European region **9** (2021)

20. GOV.UK: Coronavirus cases in the UK: daily updated statistics (2021). https://coronavirus.data.gov.uk/
21. Dobbs, T.D., Gibson, J.A.G., Fowler, A.J., Abbott, T.E., Shahid, T., Torabi, F., et al.: Surgical activity in England and Wales during the COVID-19 pandemic: a nationwide observational cohort study. Br. J. Anaesth. **127**(2), 196–204 (2021)
22. Tonna, J.E., Hanson, H.A., Cohan, J.N., McCrum, M.L., Horns, J.J., Brooke, B.S., et al.: Balancing revenue generation with capacity generation: case distribution, financial impact and hospital capacity changes from cancelling or resuming elective surgeries in the US during COVID-19. BMC Health Serv. Res. **20**(1), 1119 (2020)
23. Mazzaferro, D.M., Patel, V., Asport, N., Stetson, R.L., Rose, D., Plana, N., et al.: The financial impact of COVID-19 on a surgical department: the effects of surgical shutdowns and the impact on a health system. Surgery **172**(6), 1642–1650 (2022)
24. Khullar, D., Bond, A.M., Schpero, W.L.: COVID-19 and the financial health of US hospitals. JAMA **323**(21), 2127–2128 (2020)
25. Dominguez, L.W., Willis, J.S.: COVID-19 and the case for medical management and primary care. J. Prim. Care Community Health **11**, 2150132720965080 (2020)
26. Mattingly, A.S., Rose, L., Eddington, H.S., Trickey, A.W., Cullen, M.R., Morris, A.M., et al.: Trends in US surgical procedures and health care system response to policies curtailing elective surgical operations during the COVID-19 pandemic. JAMA Netw. Open **4**(12), e2138038 (2021)

Management of Small and Medium-Sized Enterprises During the COVID-19 Pandemic in the Slovak Republic

Ľubomíra Strážovská and Branislav Borecký

Abstract The COVID-19 pandemic has affected our entire business life. This was particularly noticeable in the business sector and especially small and medium-sized enterprises. We watched daily what problems this important part of the national economy was going through. For many businesses, the two years of the COVID-19 pandemic have been devastating. On the contrary, new enterprises were created that began to deal with a different subject of activity. The choice of the topic of the chapter is topical because it maps the current state of the COVID-19 pandemic. The aim of the chapter is the impact of the COVID-19 pandemic on the business sector in the Slovak Republic. The scientific research methods used were analysis and synthesis, deduction and a questionnaire survey that showed the problems of small and medium-sized enterprises in Slovakia. The results of the chapter represent proposals for the renewal and revitalization of small and medium-sized enterprises in Slovakia.

Keywords Small and medium-sized enterprises · COVID-19 pandemic · Business management · Economic impact · Family businesses · Slovakia economy

1 Introduction

The development and dynamics of small and medium-sized businesses and their economic results is an essential element of the development of every country. Small and medium-sized enterprises as well as family enterprises have characteristics such as flexible, progressive, motivating, stimulating and are also carriers of employment

Ľ. Strážovská (✉) · B. Borecký
Faculty of Management, Comenius University Bratislava, Odbojárov 10, Bratislava, Slovak Republic
e-mail: lubomira.strazovska@fm.uniba.sk

B. Borecký
e-mail: branislav.borecky@fm.uniba.sk

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2024

P. Štarchoň et al. (eds.), *Data-Centric Business and Applications*, Lecture Notes on Data Engineering and Communications Technologies 213,
https://doi.org/10.1007/978-3-031-62213-7_20

[2]. On the other hand, they are also a sensitive indicator of all political, environmental, legal, and economic changes, to which they react very quickly and sensitively. Especially in the current era marked by the COVID-19 pandemic.

In the ongoing process of modernization and digitization of the national economy of Slovakia and its adaptation to global trends as well as globalization trends, small and medium-sized as well as family businesses became an important element of the Slovak national economy [27]. Every day we are aware of the importance of these businesses precisely because of the various factors that we will mention in this thesis.

Well-developed management in small, medium, and family businesses is a part of functioning businesses in the national economy. Business management consists of many actions that a manager must perform. These are activities such as: leading people, making decisions, controlling, hiring employees. Especially in family businesses, e.g., admission process very important.

Small and medium-sized entrepreneurs began to receive significant attention in the European area after 1971, when the so-called The Bolton Report, which defined small and medium-sized enterprises in general with the following characteristics:

1. small and medium-sized enterprises have a relatively small share of the market and practically cannot significantly influence the market in any way,
2. small and medium-sized enterprises are managed by business owners, families, owners, or co-owners, and not mediated through a formal management structure,
3. small and medium-sized enterprises are independent enterprises, they do not form part of another larger enterprise [9].

This act changed the public's thinking about this type of business. More attention and emphasis began to be paid to them. We can assume that there has been a significant shift in interest in this type of business since World War II.

The forecasts for the performance of the Slovak economy for 2020 and 2021 were less favorable. Slovakia's economy was mainly affected by the economic effects of the COVID-19 pandemic. The economic recovery therefore depended to a large extent on the development of the epidemiological situation, the revival of foreign demand, as well as the ability to adopt support measures and the rate of drawing financial aid intended for business entities whose economic activity was stopped or limited by the impact of taking measures to mitigate the coronavirus pandemic in the (Fig. 1) Slovak republic [28].

1.1 Relevance

The COVID-19 pandemic has affected the entire entrepreneurial life. It marked primarily the business sector and mainly small and medium-sized enterprises. We watched daily what problems this important part of the national economy was going through. For many businesses, the last two years have been liquidation. On the contrary, new enterprises were created that began to deal with a different subject of

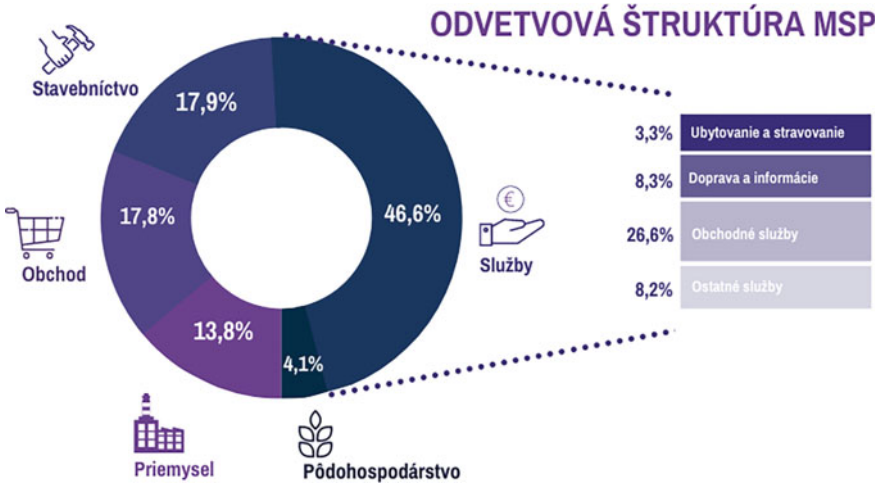


Fig. 1 Industry structure of small and medium. *Source* [39]

activity. The whole company seems to have changed and we are still following its development as well as the development of the business environment.

The choice of topic is very important because it maps the current state of the COVID-19 pandemic and its impact on the business sector in the Slovak republic. It should be noted here that the situation was also marked by the start of the war between Russia and Ukraine. The purpose of the goal was to map the situation in the business sector in Slovakia during the COVID-19 pandemic and to make proposals for the renewal and continuation of small and medium-sized businesses as well as family businesses [46].

The contribution contains interesting and up-to-date information in the business sector in Slovakia and comparisons with Germany as a developed economy.

The aim of the paper is to propose measures to reduce the adverse impact of the COVID-19 pandemic based on the conducted survey. The survey was conducted during the difficult period of the pandemic as well as the beginning of the fighting between Russia and Ukraine.

1.2 Goals and Objectives

The goal of the contribution was to express one's own opinions and proposals in the field of business environment management in Slovakia after the period of the COVID-19 pandemic.

Since the current situation in the last three years was significantly affected by the COVID-19 pandemic, we considered it necessary to look at the state of business in Slovakia compared to the advanced economy of Germany. We think that our country

could adopt several measures that could restart businesses from a more advanced economy. Measures in the field of management and business management are also a matter of course.

The sub-goals are as follows:

- study of professional domestic as well as foreign literature and professional sources,
- analysis of all sources and selection of sources,
- description of the current situation in the business sector during the COVID-19 pandemic,
- description of the form of businesses—family businesses,
- characteristics of the state of family businesses during the COVID-19 pandemic in Slovakia,
- carrying out a questionnaire survey on a selected sample of respondents.

To fulfill the goal of the work, we will use basic scientific methods such as: analysis and synthesis, deduction as well as induction. In the third chapter, we will use the descriptive method, where we will describe the current situation in the business environment from the manager's point of view, under the influence of the COVID-19 pandemic. To better ascertain the situation, we conducted a survey where we found out the problems of small and medium-sized as well as family businesses.

It was necessary to personally go to the respondents and address them. In the end, it was possible to fill out 36 questionnaires together with the respondents. Not all respondents answered all questions [41]. Overall, due to saving time, conditions, and the willingness of the respondents, we shortened the survey to 11 questions, with which we fulfilled the goal of the diploma thesis. Finally, we made our own suggestions based on the results.

We conducted the survey between 10.6.2021 and 30.3.2022 through a questionnaire that was sent to respondents by email or in person. Personally, because (as we mentioned) the businesses did not operate in normal mode and it was also more difficult to contact the owners or managers. Enterprises operated in a provisional mode. We obtained the survey sample by a targeted selection of respondents, so that the sample for our final diploma thesis was as diverse as possible, in terms of age and education. A total of 36 respondents filled out the questionnaire. Most respondents were between 40 and 50 years old, the least between 30 and 40 years old. We used a quantitative survey to gather information. The source for obtaining information in the research part was the aforementioned questionnaire. Its completion was anonymous and voluntary. The questionnaire contained 11 questions. Respondents had the opportunity to choose one of several options. The questionnaire also contained open questions, which gave us a good overview of the issues under investigation [48].

The questions were created on the basis of finding out the current situation in the Slovak business environment, and the current situation of small and medium-sized as well as family businesses in Slovakia. We honestly selected the respondents based on the following criteria:

- Whether the enterprise is a small and medium-sized enterprise or a family enterprise,
- Whether the respondent is an owner/manager or an employee,
- What problems accompanied the company during the COVID-19 pandemic.

Four research questions were asked for the survey:

1. How has the COVID-19 pandemic affected managers/owners?
2. What is the opinion of managers/managers on the development of business culture?
3. What products could companies offer after the end of the covid-19 pandemic in Slovakia?
4. How did customer priorities change during the COVID-19 pandemic?

We summarized the questions as well as the answers into groups according to the topic and into individual sub-chapters and sections [32]. We alternated the evaluation graphically as needed, using pie charts, column charts, bar charts or contingency charts. We left the questions in the text under the original designation. We did not mark the images, as they are the work of the author of the diploma thesis.

2 Theoretical and Conceptual Background

In theory as well as in economic practice, there are many definitions of small and medium-sized as well as family businesses. There is no universally accepted or used definition in the world. It is primarily due to the heterogeneity of small and medium-sized enterprises. In theory, we can see or study different definitions according to size structure by individual authors [5, 49].

Several criteria are adopted for the classification of small and medium-sized enterprises. But only some are used in economic practice. We present the criteria used in our thesis as well as in the first chapter.

The most frequently used criteria in economic practice are qualitative and quantitative criteria. We will also characterize them in the following subsections (Table 1).

Quantitative or numerical criteria of small and medium-sized as well as family businesses have the following definition in European countries:

Table 1 Criteria for small and medium-sized enterprises

Quantitative criteria	Qualitative criteria
More commonly used as quality criteria	More difficult to assess or difficult to assess
More precise than qualitative criteria	They can be inconsistent
Uniform criteria in EU countries	They can be biased

Source [6]

- number of annual sales achieved;
- value of investment property;
- size of production;
- market share size;
- number of employees;
- amount of invested capital or value of assets.

At this point, we must state that the most frequently used criterion is the number of employees. This criterion is used in all countries of the European Union. This criterion can sometimes be misleading due to the size of the company, or the sales achieved in the company. At this point, however, it should be noted that the individual states of the European Union may still have their own special specifics when being included in individual categories [3].

For further definitions, we can look at the European Commission (EC) defines an enterprise as, an entity that carries out economic activity, regardless of its legal form [10].

The determining factor is the economic activity, not the legal form. For this reason, according to the EC, self-employed persons and family businesses that carry out craft or other activities, commercial companies, partnerships, or associations that regularly carry out economic activity can be classified as enterprises [25].

Based on the recommendation of the European Commission 2003/361/EC on the definition of SMEs, the group of small and medium-sized enterprises includes business entities that employ less than 250 people and whose annual turnover does not exceed 50 million Euros and/or the total annual balance sheet does not exceed 43 million Euros. The individual size categories of SMEs are determined according to the threshold values of the above-mentioned criteria, while we distinguish three categories [10].

The following Fig. 2 illustrates the division of enterprises into individual categories of micro, small and medium-sized enterprises according to various criteria.

As we mentioned above, the comparability of individual criteria and individual approaches to the quantitative definition of SMEs in different countries is made

	Mikropodnik	Malý podnik	Stredný podnik
Zamestnanci	< 10	< 50	< 250
Ročný obrat	≤ 2 mil. Eur	≤ 10 mil. Eur	≤ 50 mil. Eur
Bilančná suma	≤ 2 mil. Eur	≤ 10 mil. Eur	≤ 43 mil. Eur

Fig. 2 Division of enterprises. *Source* [47]

difficult by the fact that, as a rule, there are several definitions in each country according to purpose [34].

In the practical application of numerical criteria for the definition of SMEs, we encounter certain limitations, and they are as follows:

– Distinguishing between business entities and facilities based on their legal as well as economic independence.
– Criterion according to the number of employees—it is necessary to define whether they are permanent employees, part-time employees.
– Criterion of achieved sales—this indicator is very variable depending on the phase in which the specific industry is located, it depends on seasonal as well as cyclical influences.
– Industry differences [33].
– Market share size criterion—often depends on other criteria as well as external influences.

2.1 Qualitative Definition of Small and Medium-Sized Enterprises

The qualitative criteria or verbal criteria according to which the size criteria of enterprises can be defined include:

- organizational factors;
- legal factors;
- social factors.

The exact addition or characterization of a certain characteristic of an SME is not possible, because a characteristic typical of an SME can also appear in a company that in other characteristics corresponds to the category of a large company [30, 31].

When qualitatively defining small and medium-sized enterprises, in our opinion, there are basically two ways to proceed:

1. By compiling a set of characteristics that are atypical for. If a given enterprise shows a specified minimum number of characteristics typical for the SME group, it can be included in this category of enterprises,
2. By the method of cluster analysis, in which enterprises are differentiated according to the accumulation—a cluster of characteristics.

World-renowned and scientifically oriented authors used the following elements to determine differences and differences as well as specifics:

- Management process.
- Organizational process.
- Sales and production.
- Research and development.
- Supply and material management.

- Financing and Research.
- The staff [44].

Other quality criteria that can also be measured or used as non-measurable criteria are the following:

- Work productivity.
- Size of sales.
- Profitability.

Here it must be stated that among the classic factors or characteristics for quality criteria we can consider the following:

- Type of management.
- Organizational structure.
- Form of ownership.
- Industry and type of market.
- The impact of the enterprise on the wider environment or the immediate vicinity of the enterprise.
- The role of the company in the region or the employment of workers from the vicinity of the company [7].

2.2 Characteristics of Family Business

Family business is the oldest form of business. This is evidenced by historical records as well as historical channels. Among the countries where this type of business has lasted the longest are the following countries: Japan, Italy, Germany, Switzerland, Spain. It is also due to the appropriate political environment [53].

Family business is a significantly used type of business in individual countries of the continents. The family is the foundation of the state. In Slovakia, attention was paid to this form of business only in the years 1900–2000, when many defunct family businesses followed up on the interrupted activity. As the author Ľubomíra Strážovská states in her publications, in the given years there was no professional or scientific literature on the given type of issue in Slovakia [43].

For family businesses, we would summarize the qualitative characteristics in the following points:

- Personality of the owner, work behavior of family members employed in the company.
- Distribution of the authority of the business owner among the family members employed in the business.
- Behavior of the family business owner towards non-family employees,
- Ethical and moral values in a family business.

Overall, we can also conclude according to the Les Henokiens organization that we can define over a hundred-year-old family businesses as businesses that have:

- "suitable" political situation;
- masculinist culture;
- religious roots.

This association unites more than a century-old family businesses all over the world. Companies join the association voluntarily for the purpose of support and exchange of experience in management and business [38, 37].

They place substantial knowledge as well as substantial emphasis on the exchange of generations and emphasis on the quality of leadership as well as the readiness of the incoming generation to lead the company.

Family businesses existed in Slovakia until 1947, later they were expropriated, and they were the businesses that operated in various industries most often:

- tourism;
- construction industry;
- banking and others.

Management as a scientific discipline is defined by Kajanova et al. as follows: … represents an accumulated and logically organized set of knowledge about the principles, methods and procedures of management and organizations in the conditions of a market economy, which are developed based on experience and the results of scientific disciplines [24].

American authors base their theory of management on technology, German authors base their theory on people, joint decision-making by workers, cooperation between capital and labor. Japanese authors develop management theory because of the peculiarity of Japan's historical development and culture. The Japanese management system was born as a counterweight to American or Western management.

There are both common and different features in the theoretical area. In the USA, the lack of influence on business activity by the government is characteristic. In Japan, highly qualified central regulation of the economy ruled, but its scope is gradually decreasing. Japanese management draws on people's experience, respects their moral, aesthetic, and emotional side.

There are both common and different features in the theoretical area. In the USA, the lack of influence on business activity by the government is characteristic. In Japan, highly qualified central regulation of the economy ruled, but its scope is gradually decreasing. Japanese management draws on people's experience, respects their moral, aesthetic, and emotional side.

The theoretical definition of the content of the economic category of management can be found in the well-known author and management experts Kajanová and Nováček [23]. We quote from his work: Management is a process focused on the effective achievement of goals, the content of which is:

- planning;
- organizing;
- leading of people;
- control.

These categories also express the basic functions of management. In the scientific works, the well-known expert Ján Rudy finds other definitions of the authors, which bring closer the understanding of the essence of this economic category, emphasizing effective integration, coordination of resources, monitoring of the achievement of goals, decision-making enabling the achievement of a set goal through other people.

It follows that this is an important process organized in the life of human society. Some authors emphasizes that it is a dynamic process that starts with defining goals, planning, implementing other functions and ending with control [13, 12].

Our task is to focus on management as a scientific discipline. The authors emphasize that it has an interdisciplinary nature. The disciplines from which it draws, as well as its own research and activities, enable the creation of new scientific knowledge, the application of which can support the growth of efficiency.

The world-famous author Ľubomíra Strážovská states that the management and development of businesses and their consequences are primary [47]. In this context, it is necessary to deal with the starting points and characteristics of management, the decision-making and information process, planning and control, organizing and organizational structure, leading people [42].

The content of the economic category management (term) is multifaceted and in the field of pedagogical process we perceive it as:

(a) science—theory,
(b) a specific activity carried out by a specific group of people.

In the current era, marked by constantly improved technologies and the COVID-19 pandemic, many skills and qualities are needed that a good manager should master.

According to Oláh et al. managers have never had to know so much before. Nowadays, every business and management process consist of the need to know as much as possible about the customer and to know a lot of activities as well as information [40]. Managers trying to run a business are subject to an abundance of information from endless sources of cybernetics. In a universal world, the advantage is on the side of universal leadership [25].

The task of a modern manager consists in more effective activities based on more effective knowledge. Hajduova et al. stated in his publication that many managers do not continue to learn and act like they already know everything. The authors also emphasizes that a business can only survive if it becomes a learning organization [50, 19].

The industrial age opened the door to the age of computerization. Currently, all forms of computerization are being activated as well as approaches to organizations are changing. According to Kononenko et al. old and well-established certainties are disappearing, and boundaries are breaking down. More and more it is becoming clear that the character of future generations and organizations is determined by people and their speed to learn everything new [29].

Computerization brought better information not only to managers but also to customers [18]. They then have greater demands on the quality and price of the product.

Rapid convergence in computer and telecommunications technologies means that information can flow through multiple channels of an organization at the same time. Many owners of family businesses find it unnecessary to employ managers in various functions. At present, the cumulation of functions and the non-sharing of positions are preferred [35].

3 Characteristics of the Business Sector in the Slovak Republic During COVID-19

3.1 Slovak Business Environment During COVID-19

In this part, we would like to characterize and describe the situation in the Slovak business environment of family businesses during the COVID-19 pandemic and also compare it with German family businesses.

By describing the categories already mentioned, we would characterize the current situation in Slovakia as well as the state of SMEs over the past two years, during the COVID-19 pandemic. For comparison, we will describe and characterize German established family businesses, which also must try to survive in the current problems with the COVID-19 pandemic. Slovak businesses could be inspired by German family businesses in terms of surviving or just surviving current problems.

In addition to the health effects, the coronavirus also has according to Čajková et al. a significant economic impact as well as an impact, especially on entrepreneurs and employers [51]. In the current situation, there are a few measures that entrepreneurs can take immediately to mitigate the economic effects of the state of emergency at least partially.

From a long-term perspective, the position of small and medium-sized enterprises (hereinafter referred to as "SMEs") in the national economy is significant, especially from the point of view of contributions to total employment, added value and support for the development of the economy [8].

According to Mimoso and Azevedo the importance of small and medium-sized enterprises can also be observed in the structure of economically active business entities [31]. In the monitored year 2020, the COVID-19 pandemic was an unreservedly central factor in the economic environment [4]. The decline in economic activity did not occur only in the Slovak republic but was also characteristic of other countries. In the European Union as a whole, the performance of the economy decreased mainly due to the collapse of important EU economies. The effects of the new type of coronavirus were also reflected in the economic performance of the sector of small and medium-sized enterprises. The unfavorable economic situation in Slovakia affected the development of the monitored economic indicators of SMEs [21].

The year 2020 was exceptional from the point of view of the development of exogenous factors, which changed the development of the Slovak and global economy in an extraordinary way. The COVD-19 pandemic was an unreservedly central factor

in the economic environment in 2020. The year 2020 was characterized not only by a significant drop in economic performance. The spread of a new type of coronavirus in 2020 was also largely associated with a relatively high degree of uncertainty and risk, which was primarily based on the development of the epidemiological situation, which is also related to the economic activity of business entities [1]. Due to the pandemic, the performance of the Slovak economy collapsed after years of continuous growth [16].

The recorded decline was the sharpest in the second quarter of 2020, in which a decrease of almost 11% was recorded. In the second half of the year, the Slovak economy was able to moderate the pace of its decline. The drop in GDP in the second half of the year was significantly lower (in the fourth quarter it was −2.1%). The decline in economic activity did not occur only in Slovakia but was also characteristic of other countries. In the European Union as a whole, the performance of the economy decreased by 6.1%, mainly due to the collapse of important EU economies [30]. Among the V4 countries, the lowest year-on-year decline in economic performance was recorded in the case of Poland. Slovakia and Hungary were placed behind Poland with a significant distance. As a result of the complex pandemic situation, the Czech Republic experienced the deepest slump among the countries of the Vyšehrad Group [36].

3.2 The Situation of Small and Medium-Sized Enterprises in the Slovak Republic

The employer is not obliged to notify the employee if the hiring, transfer to another workplace, assignment or transfer to another job, introduction of new technology, new work procedure, or new work tool occurred during an extraordinary situation, state of emergency or state of emergency declared in in connection with the disease COVID-19 (hereinafter referred to as a crisis situation) and if it is objectively impossible to fulfill this obligation; however, failure to fulfill this obligation must not immediately and seriously endanger life and health. The employer is obliged to inform the employee as soon as possible, at the latest within one month from the day of the withdrawal of the crisis.

The period, the end of which falls on the duration of the crisis, rests during the duration of the crisis situation. The deadline, the end of which falls within one month from the date of the withdrawal of the crisis, is preserved if the employer fulfills the notification obligation within one month from the date of the withdrawal of the crisis situation at the latest [36, 42]. The provisions of the first sentence and the second sentence apply only if it is objectively impossible to fulfill the notification obligation within the original deadline; failure to fulfill the notification obligation within the original deadline must not, however, immediately and seriously endanger life and health [45].

Own resources are limited, the support policy must be precisely determined. It is expected mainly with the help of European funds. The most threatened are the culture and tourism sectors, but also industrial companies [52].

Occupancy of accommodation capacities is extremely low, corporate clients who have not yet canceled booked events are doing so now. Given the limitation of own resources, the policy must be precisely targeted. Eurofunds are the bearers of a strong fiscal stimulus [14, 15]. The hottest candidates for such help are the culture, sports and accommodation sectors. Industrial companies blamed this on the low limit of aid per employee, which was, for example, EUR 880 under the Kurzarbeit scheme. Help to maintain employment must come immediately and forcefully. The government will not avoid compensations.

3.3 Proposals for Measures to Mitigate the Effects of the COVID-19 Pandemic

Measures presented by the government:

1. The state reimburses 80% of the employee's salary to all companies whose operations are compulsorily closed. Companies have been closing operations by order of the state since March 12, 2020.
2. If the company's sales fall by more than 20%, the state will contribute to the company and self-employed workers' salaries according to the amount of the losses. The government would like to start paying the contributions as early as April 15, 2020.
3. Provision of bank guarantees in the amount of 500 million euros per month. The reason is that banks are willing to lend money to entrepreneurs and companies.
4. For employees in quarantine and parents in nursing care, the state will always pay 55% of their gross salary. While in the past the maximum period of receipt of sick leave could be ten days, now the length has moved up to 101 days.
5. Postponement of the payment of levies for the employer if his sales fall by more than 40%.
6. Postponement of income tax advances in the event of a decrease in sales by more than 40% [26].

If the unions and employers do not agree on a new minimum even in 2020, it will be decided by the formula determined by law by the previous government. According to him, its new amount will be 656 euros.

According to Jančíková and Pásztorová in 2020, the minimum wage valid for 2021 will be set. Until 2019, the minimum wage was set by the state, unless the trade unions and employers reached an agreement. And they practically never agreed, that's why the state decides on the level of the minimum wage [22].

If, even in 2022, the unions and employers do not agree on a new level of the minimum wage, which is very likely from experience, it will be decided by the

formula determined by law by the previous government, according to which the new minimum wage will be 656 € [17].

We are currently entering a recession due to the coronavirus pandemic. The formula is supposed to determine the value of the minimum wage until "bad times" based on data from "good times", and that is dangerous [42].

There is no consensus in the Slovak republic or abroad about the impact of minimum wages on the economy. There are areas in which the growth of minimum wages causes positive development, in others its impact can be understood negatively. The nature of these conflicting influences cannot be unequivocally determined. Some are oriented more towards the market and business environment, others towards the cohesion and social stability of the population or the reduction of regional disparities. The opinion on the minimum wage is thus naturally different depending on which values are given greater weight [51, 20].

4 Results of a Questionnaire Survey

4.1 Questionnaire Survey

The selected small and medium-sized enterprises and their managers had difficulty keeping the business running, or surviving with the business, so they were not very willing to fill out the questionnaire. It was necessary to personally go to the respondents and address them. In the end, it was possible to fill out 36 questionnaires together with the respondents. Not all respondents answered all questions. Overall, due to saving time, conditions and the willingness of the respondents, we shortened the survey to 11 questions, with which we fulfilled the goal of the diploma thesis. Finally, we made our own suggestions based on the results.

We conducted the survey between 10.6.2021 and 30.3.2022 through a questionnaire that was sent to respondents by email or in person. Personally, because (as we mentioned) the businesses did not operate in normal mode and it was also more difficult to contact the owners or managers. Enterprises operated in a provisional mode. We obtained the survey sample by a targeted selection of respondents, so that the sample for our final diploma thesis was as diverse as possible, in terms of age and education.

A total of 36 respondents filled out the questionnaire. Most respondents were between 40 and 50 years old, the least between 30 and 40 years old. We used a quantitative survey to gather information. The source for obtaining information in the research part was the aforementioned questionnaire. Its completion was anonymous and voluntary. The questionnaire contained 11 questions. Respondents had the opportunity to choose one of several options. The questionnaire also contained open questions, which gave us a good overview of the issues under investigation.

We used Forms to fill out the questionnaire. We deliberately did not indicate the percentage. The questions were created on the basis of finding out the current

situation in the Slovak business environment, and the current situation of small and medium-sized as well as family businesses in Slovakia. We honestly selected the respondents based on the following criteria:

- whether the enterprise is a small and medium-sized enterprise or a family enterprise;
- whether the respondent is an owner/manager or an employee;
- what problems accompanied the company during the COVID-19 pandemic.

Four research questions were asked for the survey:

1. How has the COVID-19 pandemic affected managers/owners?
2. What is the opinion of managers/managers on the development of business culture?
3. What products could businesses offer after the end of the COVID-19 pandemic in Slovakia?
4. How customer priorities changed during the COVID-19 pandemic?

We summarized the questions as well as the answers into groups according to the topic and into individual sub-chapters and sections. We alternated the evaluation graphically as needed, using pie charts, column charts, bar charts or contingency charts. We left the questions in the text under the original designation.

4.2 Value Co-creation from a Second-Order Perspective

One of the initial questions was the age of the respondent. Most respondents were between 40 and 50 years old. The least was 20–30 years old. We displayed the result of the question on a pie chart as well as a column chart. We did not state the percentage. We have highlighted the largest sample of respondents in bold.

The question of the highest education came out as follows: the most respondents, 15, have a university education, and the result of primary education is interesting—9 respondents. We found that even respondents with basic education own and manage a business. Even basic education was not a problem for entrepreneurs or managers of micro or small construction companies who had to hire employees during the COVID-19 pandemic, because there was a lot of interest in their products. During a personal interview with the respondents, we learned more and that the respondents with basic education are micro or small construction companies, where skill and practical experience are more important than education. We display the results on a pie chart as well as a column chart.

The given question was asked to the respondents personally, as it preceded the explanation. The questions related to problems in the respondent's company, namely the dismissal of employees, the hiring of employees, or directing the employee to an agreement on the performance of work or the termination of business activity. The results were as follows: up to 13 respondents had their employees dismissed,

or 9 respondents had to close their business. In six of the respondents' companies, employees had to switch to a work activity agreement. In essence, the survey confirmed the situations that were also reported in the media, that small and medium-sized enterprises, as well as family businesses, had to fire their employees or legally modify their contracts. The complete termination of business activity was also a sad state. Only four respondents saw that they had to hire employees during the Covid-19 pandemic.

From internal interviews, we learned that these are micro and small enterprises operating in the construction industry.

Question number 5 was asked simply. We asked whether the respondents consider state aid or support for businesses to be sufficient. 28 respondents stated that they did not consider the assistance to be sufficient. Since the respondents were business owners or managers, we consider this answer sufficient.

The sixth question was aimed at the biggest negative phenomenon during the Covid-19 pandemic, namely the termination of business or the closing of retail establishments. Respondents registered the termination of business activity as well as the closure of retail operations of businesses in their vicinity. As they personally expressed during the survey, the reasons were as follows:

- subsequent departure to a better and safer workplace;
- less interest of customers as well as end consumers to buy products;
- In some cases, also the death of the owner or manager because of the COVID-19 pandemic [11];
- lack of requested (customer) goods.

The issue of business culture is very important, and the state has been dealing with it for a long time. That is also why we included it among the questions in the questionnaire. We were interested in how the COVID-19 pandemic affected relations between entrepreneurs, whether they improved or worsened.

From the open question in the questionnaire, we can infer very diverse answers or opinions of entrepreneurs. Overall, we can conclude that two types of answers prevail:

- Entrepreneurs/respondents state that business ethics have not changed even due to the impact of the pandemic and relations between entrepreneurs are still negative.
- Respondents state that due to the pandemic, relations are improving, and entrepreneurs are trying to improve their business environment.

Some answers were interesting and influenced by the subject of the activity. As, for example, a manager in the IT industry praised that time because he had a larger number of orders than before.

One respondent had an interesting and thought-provoking opinion, stating that the business sector has been cleared of non-payers and expects that the younger generation will have better manners in business.

We have seen the opinions on the open question in this sub-chapter, and after reading it, we can conclude that managers and even entrepreneurs have diverse opinions on the given issue.

5 Applying Survey Results

5.1 The Way the COVID 19 Pandemic Affected Small and Medium-Sized Businesses in the Slovak Republic

The last question was still mentioned as a discussion question in the media as well as on social networks. Almost every small and medium-sized as well as family business was marked in some way. In the following open question, we found out how the pandemic affected the investigated company.

Many respondents expressed themselves in the same way, and we summarized their answers (according to frequency) into the following points:

- managers/owners had to fire their employees,
- it was also related to a decrease in sales and a decrease in customer interest in the product being sold,
- the owners had to outsource their own employees to the Agreement on performed activities,
- craftsmen as well as IT experts, on the other hand, had more orders and their sales increased,
- in some cases, the owner also resorted to private financial resources to maintain the business,
- in four cases, the owner had to end business activity,
- if the owner somehow managed to maintain the business even with the dismissal of employees, he now has a problem finding trained employees. It plans to employ Ukrainian citizens.

5.2 Changes in Customer Behavior

Another question was aimed at changes in customer priorities. The respondents, managers, or business owners felt changes in customer behavior and shopping during the COVID-19 pandemic. It was also reflected in the sales of their businesses. Changes must be considered and dealt with. The war between Ukraine and Russia also brought or will bring changes.

Regarding the answers to the open question of the respondents, they expect new relationships between customers, new products as well as new ethical principles in business.

6 Conclusion

6.1 Synopsis

In previous subsections as well as sections, we commented on the results of the survey and evaluated the individual questions of the questionnaire.

We started from the goal of the work as well as the research questions, which were as follows:

1. How has the COVID-19 pandemic affected managers/owners?
2. What do managers/managers think about the development of business culture?
3. What products could businesses offer after the end of the COVID-19 pandemic in Slovakia?
4. How did customer priorities change during the COVID-19 pandemic?.

We can conclude that we have received answers to our research questions.

The COVID-19 pandemic has significantly affected both business owners and managers. We found out that the owners but also the managers, sometimes in one person, had big problems during this period. We can briefly summarize them in the following points:

A. They had to lay off a certain number of employees,
B. In the case of family businesses, they had to reach into family resources to keep the business afloat,
C. They had to reorient themselves to a different product that customers were buying,
D. Some had to end their business activities,
E. Businesses that provided IT services, on the other hand, had to hire new employees due to the greater interest of customers in their products,
F. If the company ended its business activity, then after releasing the cautious, on the contrary, it had to look for new employees.

In the research question as well as the question in the survey about the development of business culture, interesting opinions and assurances also appeared. Most respondents claimed that the business culture improved, as it were, by cleaning up relations between businessmen. They considered it natural that after a difficult period, relations between entrepreneurs improved. There is a certain percentage of respondents who do not deal with business culture, but they are few.

This research question produced interesting results. Because the answers to the questions seemed to signal a return to the original values. The respondents answered as follows what products they would like and what they would buy:

1. Quality Slovak food.
2. High-quality Slovak home products.
3. Nutrition and health products.
4. Domestic Slovak products.

As for the open question regarding business culture during and after the pandemic (events in the east of Ukraine interfered with the writing period of the thesis), managers or owners stated that business culture in Slovakia has slightly improved. In personal interviews with the respondents, they expressed themselves as follows:

1. The manager/owners paid their financial obligations.
2. The manager/owners respond to emails faster.
3. The manager/owners communicate more directly and openly.
4. Manager/owners value orders for goods more.

References

1. Adamisin, P., Kotulic, R., Mura, L., Kravcakova Vozarova, I., Vavrek, R.: Managerial approaches of environmental projects: an empirical study. Pol. J. Manag. Stud. **17**(1), 27–38 (2018). https://doi.org/10.17512/pjms.2018.17.1.03
2. Aksamovic, D., Simunovic, L.: The EU scheme for the state aid rules in the air transport sector during the Covid-19 crisis. Juridical Trib. **12**(1), 51–67 (2022)
3. Aksamovic, D., Simunovic, L.: The EU scheme for the state aid rules in the air transport sector during the Covid-19 crisis. Juridical Trib. **12**(1), 51–67 (2022). https://doi.org/10.24818/TBJ/2022/12/1.04
4. Androniceanu, A., Popescu, C.R.: An inclusive model for an effective development of the renewable energies public sector. Adm. Si Manag. Public **2017**(28), 81–96 (2017)
5. Bauer, C., Kryvinska, N., Strauss, C.: The business with digital signage for advertising. Lect. Notes Inf. Syst. Organ. **15**, 285–302 (2016)
6. Beták, N., Csapó, J., Horváth, Á., Dávid, L. D.: Virtual tour as a virtual experience of destination management organisations in Slovakia. Geoj. Tour. Geosites **47**(2), 508–514 (2023). https://doi.org/10.30892/gtg.47218-1050
7. Brestovanska, P., Kajanova, J.: Simple company on shares as startup support tool. Acta Univ. Agric. Silviclturae Mendel. Brun. **66**(6), 1601–1611 (2018). https://doi.org/10.11118/actaun201866061601
8. Cajková, A., Jankelová, N., Masár, D.: Knowledge management as a tool for increasing the efficiency of municipality management in Slovakia. Knowl. Manag. Res. Pract. **21**(2), 292–302 (2023). https://doi.org/10.1080/14778238.2021.1895686
9. Dudic, B., Dudic, Z., Pejanovic, R., Skataric, G., Saxunova, D.: The rural policy of Slovakia after joining the EU. Agric. For. **66**(3), 33–51 (2020). https://doi.org/10.17707/AgricultForest.66.3.04
10. European Commission: Recommendation No. 2003/361/EC of 6 May 2003 concerning the definition of micro, small and medium-sized enterprises. Available online at: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:124:0036:0041:en:PDF
11. Fedushko, S., Mastykash, O., Syerov, Y., Peracek, T.: Model of user data analysis complex for the management of diverse web projects during crises. Appl. Sci. **10**, 9122 (2020). https://doi.org/10.3390/app10249122
12. Funta, R.: Economic and legal features of digital markets. Danube **10**(2), 173–183 (2019). https://doi.org/10.2478/danb-2019-0009
13. Funta, R.: Relationships between platforms and retailers (on the Example of Amazon). AUC IURIDICA **69**(2), 83–94 (2023). https://doi.org/10.14712/23366478.2023.16
14. Funta, R., Králiková, K.: Obligation of the European commission to review national civil court judgements? Juridical Trib. **12**(2), 215–226. https://doi.org/10.24818/TBJ/2022/12/2.04
15. Funta, R., Buttler, D.: The digital economy and legal challenges. Intereulaweast **10**(1):145–160 (2023). https://doi.org/10.22598/iele.2023.10.1.8

16. Gregušová, D., Halásová, Z.: EIDAS regulation and Its impact on national legislation: the case of the Slovak Republic. Adm. Sci. **12**(4), 187 (2022). https://doi.org/10.3390/admsci12040187
17. Groza, A.: The principle of mutual recognition: from the internal market to the European area of freedom, security and justice. Juridical Trib. **12**(1), 89–104 (2022)
18. Gubíniová, K., Štarchoň, P., Vilčeková, L., Bartáková, G.P., Brtková, J.: Marketing communication and its role in the process of creating rational awareness of generation Z representatives. Stud. Syst. Decis. Control. **376**, 203–221 (2021). https://doi.org/10.1007/978-3-030-76632-0_6
19. Hajduova, Z., Coronicova Hurajova, J., Bruothova, J.: Determinants of innovativeness of Slovak SMEs. Probl. Perspect. Manag. **19**(1), 198–208 (2021). https://doi.org/10.21511/ppm.19(1).2021.17
20. Horvat, M., Magurová, H., Srebalová, M.: Protection of consumers' rights in railway in the Slovak republic. Yearb. Antitrust Regul. Stud. **10**(16), 177–190 (2017). https://doi.org/10.7172/1689-9024.YARS.2017.10.16.9
21. Ispas, G.L.: Impact of the covid-19 on the migration in the European union. Juridical Trib. **11**(1), 30–41 (2021)
22. Jančíková, E., Pásztorová, J.: Promoting eu values in international agreements. Juridical Trib. **11**(2), 203–218 (2021). https://doi.org/10.24818/TBJ/2021/11/2.04
23. Kajanova, J., Novacek, P.: Environmental crimes and bentonite mining and processing companies in Slovak Republic. TalTech J. Eur. Stud. **12**(2), 43–63 (2022). https://doi.org/10.2478/bjes-2022-0011
24. Kajanová, J., Matúšová, S., Nováček, P.: Sustainable business in the European economic area. Juridical Trib. **12**(4), 495–508 (2022). https://doi.org/10.24818/tbj/2022/12/4.04
25. Kaššaj, M.: The influence of jurisprudence on the formation of relations between the manager and the limited liability company. Juridical Trib. **13**(1), 43–62 (2023). https://doi.org/10.24818/TBJ/2023/13/1.04
26. Khorsand, P.N.N.-H.: Home office—benefit for employer or employee? Stud. Syst., Decis. Control **462**, 349–373 (2023). https://doi.org/10.1007/978-3-031-25695-0_16
27. Kita, P., Maciejewski, G., Čvirik, M., Mazalánová, V.K.: New factors of consumer behaviour in the context of business models used in retailing during the COVID-19 era. Forum Sci. Oecon. **10**(3), 75–92 (2022). https://doi.org/10.23762/FSO_VOL10_NO3_4
28. Kita, J., Máziková, K., Grossmanová, M., Kita, P.: Trade practices of retail chains as far as the transaction cost analysis in the relationships manufacturer—retailer are concerned in the milk industry. Agric. Econ. (Czech Repub.) **58**(6), 264–274 (2012). https://doi.org/10.17221/61/2011-agricecon
29. Kononenko, I., Stepanova, O., Bukrieieva, K., Kononenko, O., Kryvinska, N.: Business game for PMBOK standard training of project managers. CEUR Work. Proc. **2565**, 71–82 (2020)
30. Matúšová, S., Nováček, P.: New generation of investment agreements in the regime of the European Union. Juridical Trib. **12**(1), 21–34 (2022). https://doi.org/10.24818/TBJ/2022/12/1.02
31. Mimoso, M.J., de Azevedo, L.C.: The need for a harmonious interpretation of the rules applicable to international contracts. Juridical Trib. **12**(1), 68–79 (2022). https://doi.org/10.24818/TBJ/2022/12/1.05
32. Mucha, B., Brestovanska, P., Kajanova, J.: Selected ways of acquiring securities in the conditions of the Slovak Republic. Acta Univ. Agric. Silv.Ulturae Mendel. Brun. **66**(6), 1589–1599 (2018). https://doi.org/10.11118/actaun201866061589
33. Mura, L., Zsigmond, T., Bakó, F., Marcell, K.: New organizational environment types based on Garvin and Quinn—the case of Slovakian small and medium enterprises. TEM J. **12**(2), 691–699 (2023). https://doi.org/10.18421/TEM122-12
34. Mura, L., Stehlikova, B.: Innovative approaches: using DEMATEL method in the research of SMEs operating in tourism sector. In: Valeri, M. (ed) Family Businesses in Tourism and Hospitality. Tourism, Hospitality & Event Management. Springer, Cham (2023). https://doi.org/10.1007/978-3-031-28053-5_10

35. Neussner, W., Kryvinska, N., Markl, E.: Bonus programs for crm in retail business. Adv. Intell. Syst. Comput. **1035**, 483–491 (2020)
36. Novackova, D.: The common European investment policy and its perspectives in the context of the Achmea case law. TalTech J. Eur. Stud. **11**(1), 153–169 (2012). https://doi.org/10.2478/bjes-2021-0010
37. Nováčková, D., Vnuková, J.: Competition issues including in the international agreements of the European union. Juridical Trib. **11**(2), 234–250 (2021). https://doi.org/10.24818/TBJ/2021/11/2.06
38. Nováčková, D., Vnuková, J.: Relationship between EU law and national law in the context of case law of judicial bodies. Juridical Trib. **12**(4), 538–551 (2022). https://doi.org/10.24818/tbj/2022/12/4.07
39. Národné podnikateľské centrum: *Monitoring MSP.* Správa o stave MSP na Slovensku v roku (2020)
40. Oláh, J., Aburumman, N., Popp, J., Khan, M. A., Haddad, H., Kitukutha, N.: Impact of industry 4.0 on environmental sustainability. Sustainability (Switzerland) **12**(11), 4674. (2020). https://doi.org/10.3390/su12114674
41. Palatický, Š, Keller, K., Mußmann, A.: European digital strategy and its impact on the conclusion of selected types of business contracts. Stud. Syst. Decis. Control **462**, 443–468 (2023). https://doi.org/10.1007/978-3-031-25695-0_20
42. Pavelek, O., Zajíčková, D.: Personal data protection in the decision-making of the CJEU before and after the Lisbon treaty. TalTech J. Eur. Stud. **11**(2), 167–188 (2021). https://doi.org/10.2478/bjes-2021-0020
43. Paškrtová, L., Nováčková, D., Vnuková, J.: Cross-border provision of services: case study in the Slovak Republic. Adm. Sci. **13**(2), 54 (2023). https://doi.org/10.3390/admsci13020054
44. Peráček, T.: Flexibility of creating and changing employment in the options of the Slovak Labor Code. Probl. Perspect. Manag. **19**(3), 373–382 (2021). https://doi.org/10.21511/ppm.19(3).2021.30
45. Skrabka, J.: The moratorium on loan repayments during the covid-19 pandemic in Europe: a comparative analysis of loan moratoria in selected European countries. Juridical Trib. **11**(SI), 291–301 (2021). https://doi.org/10.24818/TBJ/2021/11/SP/02
46. Srebalová, M., Mucha, B.: Nuclear waste potential and circular economy: case of selected European country. Stud. Syst. Decis. Control **462**, 271–292 (2023). https://doi.org/10.1007/978-3-031-25695-0_13
47. Strážovská, Ľ.: Marketing malého, stredného a rodinného podnikania. Sprint2, Bratislava (2019)
48. Vilcekova, L., Strazovska, L.: Selected problems of family business: a case study from Slovakia. Acta Polytech. Hung. **17**(7), 145–162 (2020). https://doi.org/10.12700/APH.17.7.2020.7.8
49. Čajka, P., Abrhám, J.: Regional aspects of V4 countries' economic development over a membership period of 15 years in the European union. Slovak J. Polit. Sci. **19**(1), 89–105 (2019). https://doi.org/10.34135/sjps.190105
50. Čajková, A., Gogová, A.: Case study of the knowledge management process in selected department of state administration in Slovakia. Stud. Syst. Decis. Control. **420**, 533–545 (2022). https://doi.org/10.1007/978-3-030-95813-8_21
51. Čajková, A., Šindleryová, I.B., Garaj, M.: The covid-19 pandemic and budget shortfalls in the local governments in Slovakia. Sci. Pap. Univ. Pardubice Ser. D: Fac. Econ. Adm. **29**(1), 1243 (2021). https://doi.org/10.46585/sp290112436
52. Čajková, A., Čajka, P., Elfimova, O.: Personality and charisma as prerequisites for a leading position in public administration. Springer Proc. Bus. Econ. 199–211 (2018). https://doi.org/10.1007/978-3-319-74216-8_21
53. Šubová, N., Mura, L., Buleca, J.: Determinants of household financial vulnerability: evidence from selected eu countries. E a M: Ekon. Manag. **24**(3), 186–207 (2021). https://doi.org/10.15240/TUL/001/2021-3-011