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Contents

INNOVATION STRATEGIES IN BUSINESS

Jozef GLOVA – Dominika FALISOVA – Alena ANDREJOVSKA

Abstract: The article deals with the innovation strategy as an important part for the success of an organization in 17 EU countries. The key period for our analysis is the years 2018 and 2020 while using regression analysis, concretely a Kolmogorov-Smirnov test (*KS test*) applied in RStudio. Based on the previous studies, the authors have concentrated their efforts on analyzing the choice between product and process innovations including varying combinations of the two, with the general conclusion that complete specialization in one type of innovation is rare. According to our analysis, it depends on which sector the company belongs to. Businesses are mostly heterogeneous while choosing the innovation strategy, companies belonging to Industry and Manufacturing chose the same strategy, they have chosen in the previous period. Electricity, gas, and steam companies changed their strategy.

Keywords: innovation, strategy, organization

Introduction

Innovation is a key to ensure the prosperity of its citizens to meet future challenges, and its implementation requires a systemic, cross-cutting and multilateral approach. Economic progress, social well-being and quality of life are based on its ability to increase growth, which depends on large extent on innovation. Innovation is also key that significantly increase the use of new technologies, as well as changes in productivity and efficiency. Effective investment of enterprises in innovation transforms them and makes them leaders in the given industry. Innovation means the introduction of a process of changes to an established system in order to increase the value of a given thing. Despite their importance, not all businesses can recognize the need for innovation and are unable to manage their innovation process. Applying innovation requires increased attention to five key factors, which include goals, actions, teams, results and communities, and the relationship between them is very important. It is important to monitor the investments that companies make in innovations, as well as the goals they are trying to achieve and, finally, to examine the reasons why the introduction of many innovations does not bring the desired growth.

Methodology and Data

The analytical part of the article is based on financial data of the enterprises by type of the innovation business strategy, belonging to the statistical classification of economic activities NACE Rev. 2- Statistical classification of economic activities in the European Community, part Manufacturing, Industry and Electricity, gas, steam. Financial data of companies in 17 EU countries* were obtained from Eurostat database, the statistical office of the European Union. The key period for our analysis was to compare years 2018 and 2020, because available financial data were reported by countries in this period. Based on an extensive analysis of professional publications dealing with the issue of innovation business strategy using a Kolmogorov-Smirnov test (*KS test*). This test can be used as goodness of fit test following regression analysis. There are no restrictions on sample size- small samples are acceptable.

* Bulgaria, Croatia, Czechia, Denmark, Estonia, Germany, Greece, Hungary, Latvia, Lithuania, Malta, Poland, Portugal, Romania, Slovakia, Slovenia, Sweden

The formula to calculate the test statistic (two-sample KS test) is following:

$$d = n \,.\, \max_{x \in R} \left| F_1(x) - F_2(x) \right| \qquad (1)$$

where

D	the KS test statistic
N	the sample size
$F_1(x)$, $F_2(x)$	empirical distribution functions of the first and the second sample

Critical field

$$d \geq d_\alpha(n) \qquad (2)$$

Differences during empirical distribution functions are investigate if the maximum difference exceeds the corresponding critical value, we favor the alternative hypothesis that the distributions differ.

According to information from Eurostat, organizations are mainly focusing on:

- **Improving existing goods or services-** can occur through changes in materials, components and other characteristics that enhance performance.
- **Introducing entirely new goods or services-** differ significantly in their characteristics or intended uses from products previously produced by the firm.
- **Reaching out to new customer groups-** it is important to thoroughly research your new and existing target audience. Research businesses already in the new markets, collaborating with like-minded companies.
- Customer specific solution- are dedicated for one customer.
- Low-price- **is a strategy in which a company offers a relatively low price to stimulate demand and gain market share.**
- High quality- contributes to the successful creation and production of products that perform well on the market.
- A broad range of goods and services- variations of a single product that are made to create similar yet distinctly different products.
- Key goods and services- the most important goods and services for a company.
- Satisfying established customer groups- is a measure of how well a company's products, services, and overall customer experience meet customer expectations.
- Standardized goods or services- use the same materials no matter where in the world it's sold, from the raw supplies used to create it to the branding, naming, and packaging.

Based on theoretical knowledge and knowledge from the conducted studies, it is possible to proceed to the formulation of hypotheses for further research

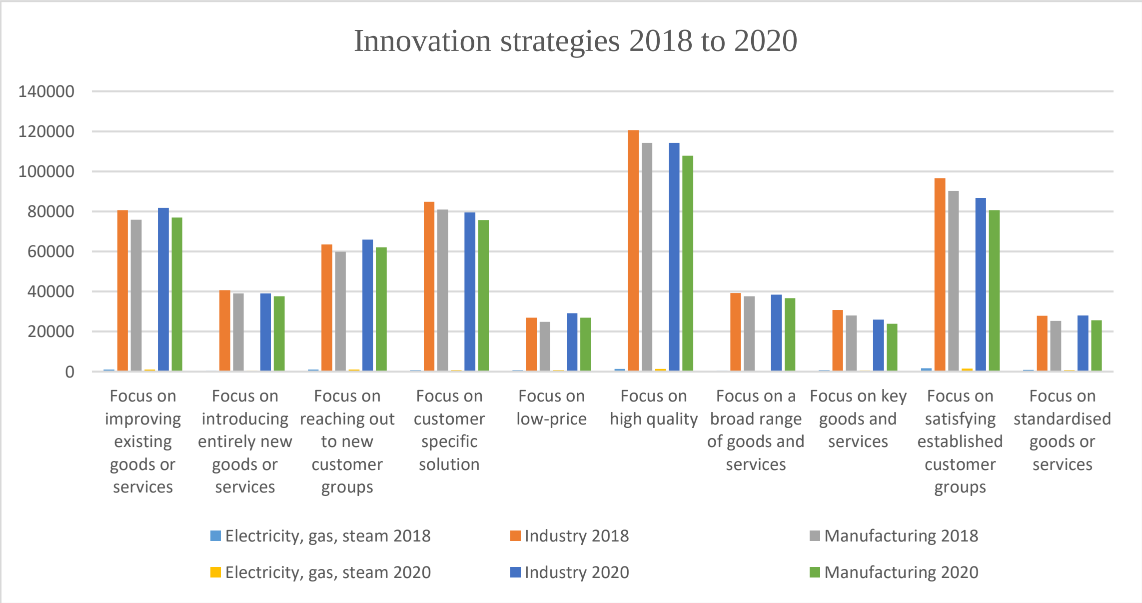
1) Firstly, we are analyzing difference between strategies, it means if companies use the same strategy in the mentioned period.
$H0_1$: Companies apply the same strategy in mentioned period.

By performing the KS test, we find out whether we accept or reject these hypotheses.

Results and Discussion

Based on an extensive analysis of professional articles and literature dealing with the important role of strategy for the success of an organization, we found out that companies make decision of their innovation strategies according to internal factors and, they are influenced by the decision, they have made before. As shown on the following graph (Figure 1), there is a difference between strategies applied by the companies in the different sectors. The most companies belong to the category of Industry (51,65% in 2018, 51,60% in 2020), then Manufacturing (48,74% in 2018, 48,72% in 2020) and the smallest group of companies is Electricity, gas, and steam (1,29% in 2018, 1,58% in 2020).

Figure 1 Companies by type of innovation strategy (compare 2018 and 2020)



Source: own processing

Based on table 1 we can tell that Manufacturing companies mostly use innovation strategy focusing on introducing entirely new goods or services in both years. The goal of this product-focused businesses strategy is producing the best product they can, regardless of the market. They believe that a superior product will always win, regardless of the market. This may mean repeatedly improving a current product rather than revamping it to meet changing needs.

Commonly used innovation strategy for Industries businesses is focusing on standardized goods or services. A standardized product uses the same materials no matter where in the world it's sold, from the raw supplies used to create it to the branding, naming, and packaging. Standardized services enable network operators to efficiently deliver services with an expectation of cross-compatibility among equipment. Vendors manufacture their products with features that guarantee support for reliable and timely delivery of data and services.

Electricity, gas, and steam companies changed their innovation strategy. In 2018, they were focusing on low-price, then they were using strategy focusing on standardized goods or services. Low pricing strategy allowed them to decrease demand fluctuations and avoid sales promotions, streamlined demand forecasting operations. A low pricing strategy enabled to set low prices for products to attract more customers and increase sales. But they changed this strategy to standardized goods and services. This strategy enables network operators to efficiently deliver services with an expectation of cross-compatibility among equipment.

Table 1 Innovation strategies

		improving existing goods or services	introducing entirely new goods or services	reaching out to new customer groups	customer specific solution	low-price	high quality	broad range of goods and services	key goods and services	satisfying established customer groups	standardised goods or services
2018	Electricity, gas, steam	0,68%	0,60%	0,78%	0,49%	1,29%	0,61%	0,28%	1,14%	0,90%	1,22%
	Industry	51,16%	50,72%	51,06%	50,99%	51,31%	51,15%	50,98%	51,46%	51,33%	51,65%
	Manufacturing	48,16%	48,68%	48,16%	48,52%	47,39%	48,24%	48,74%	47,39%	47,77%	47,13%
2020	Electricity, gas, steam	0,67%	0,53%	0,78%	0,42%	1,26%	0,57%	0,47%	1,32%	0,86%	1,58%
	Industry	51,19%	50,75%	51,13%	50,93%	51,41%	51,07%	50,85%	51,55%	51,30%	51,60%
	Manufacturing	48,14%	48,72%	48,09%	48,65%	47,33%	48,36%	48,67%	47,12%	47,85%	46,82%

Source: own processing

We applied statistical K-S test to analyze if companies use the same strategy in the mentioned period. The results are following:

Electricity, gas, steam

From the output we can see that the test statistic is **0,061947** and the corresponding p-value is **0,04301**. Since the p-value is smaller than 0,05, we decline the null hypothesis. We have sufficient evidence to say that the two sample datasets do not come from the same distribution. We can decline hypothesis $H0_1$ and say that companies do not apply the same strategy in mentioned period.

Industry

From the output we can see that the test statistic is **0,057895** and the corresponding p-value is **0,9078**. Since the p-value is greater than 0,05, we accept the null hypothesis. We have sufficient evidence to say that the two sample datasets come from the same distribution. We can accept hypothesis $H0_1$ and say that companies apply the same strategy in mentioned period.

Manufacturing

From the output we can see that the test statistic is **0,051673** and the corresponding p-value is **0,9001**. Since the p-value is greater than 0,05, we accept the null hypothesis. We have sufficient evidence to say that the two sample datasets come from the same distribution. We can accept hypothesis $H0_1$ and say that companies apply the same strategy in mentioned period.

The purpose of this article was to analyze mostly used innovation strategy in the different sectors. We came to the same conclusion as researchers *Karlsson & Tavassoli (2015)* that firms are heterogeneous in their preferences of choices to innovation strategy and not only choose from wide range of choices, but also tend to persist to choose whatever they have chosen in the previous period. We also agree with *Tavassoli (2014)* that the decisions that are taken are influenced by the internal characteristics of firms as well as by the characteristics of the external context within which they operate. While firms over time partly can change their strategies, they must accept that the context is shaped by external factors that they can’t influence. Different variables have different impacts on the various innovation strategies and might interact in different ways.

This study has also limitation of the dataset. The data only includes information from 2018 to 2020 for 17 EU countries. In view of the distinct structural change of the economy in the last decade (rapid technological change, globalization, international trade, competitiveness, etc.), an analysis with more data might have provided additional insights. The research of the firms' innovation strategies draws on unbalanced data, with the consequence that we could deal only with strategic switches taking place over a relatively short period.

Conclusion

The purpose of the article was to deal with the innovation strategy as an important part of the success of an organization in 17 EU countries. *Firstly,* we have analyzed theoretical sources and research about innovation strategies applied. Such a theory-based assessment of the most common strategies applied of statistical methods is missing in previous research.
Secondly, we were collecting suitable data for our research. The examined sample contains information from 17 EU countries from 2018 to 2020 according to data availability. The study has used this data from the Eurostat.
Finally, we have examined if companies use the same strategies on year-to-year basis or tend to change it. We found that it really depends on sector. Manufacturing and Industrial companies did not change their innovation strategy during studied period, but Electricity, gas, and steam did.

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PHOTOGRAMMETRIC 3D DIGITIZATION OF THE HUMAN HEAD

Teodor TÓTH – Lucia BEDNARČÍKOVÁ

Abstract: The use of innovative technologies for taking measurement data as well as production enables efficient, relatively simple, fast creation of data for the production of O&P aids. The paper deals with the use of photogrammetry in the digitization of the human head by the walk-around method with the using 1 camera, evaluation of selected dimensions and their comparison with manually taken measures. The RealityCapture software was used to create the digital model, the output of which is a head model with a realistic texture with sufficient details. Using the GOM Suite 2019 software, selected anthropometric measurements of the model were carried out before comparing them with those obtained using traditional measurement of a living subject, which we considered the reference. According to the results, the obtained head model contains sufficient details (face surface, texture). Photogrammetry is applicable because the results of measurement do not differ significantly from the reference measurements.
Keywords: photogrammetry, measurement, walk-around method, head digitization

Introduction

The trend for obtaining measurement data in prosthetics and orthotics (O&P) field is the use of digitization of the human body and the manufacturing of aids using low-cost 3D printers. The combination of technologies allows experts in the field to design and manufacture personalized orthopedic equipment in the online space without visiting a O&P workplace.

It is possible to digitalize humans or human body parts for various reasons, for example, for use in medical training and education process (anatomical models) (Petriceks et al., 2018); defects or deformities detection, in the orthopedics (disease diagnosis, monitoring of treatment), creation of orthopedic-prosthetic devices (materials for orthoses, prostheses) (Ciobanu et al., 2013; Grazioso et al., 2019; Hernandez & Lemaire, 2017; Lee, 2017; Matthews, 2008; Taqriban et al., 2019); anthropometry (human morphometric parameters) (Zappa et al., 2010) and others.

The current trend of digitization offers various possibilities how to obtain a 3D digital model. These methods can be structured light scanning, triangulation laser scanning, photogrammetry and more. Photogrammetry is the applied science of using photographs to represent an object in 3D (three-dimensional reconstruction of an object in digital or graphic form), which combines the advantages of photographs, videos, and computerized models while avoiding most of their drawbacks. The basis of photogrammetry is the image, which is, under certain conditions, the exact central projection of the photographed image. In photogrammetry, 2D photographs of an object are taken at varying angles and then overlaid using computer software to generate a 3D reconstruction. The software is used to identify common points between images taken at differing angles and then to overlay the images by matching their common points (Petriceks et al., 2018). This method can be used as an alternative to conventional 3D scanners.

Photogrammetry offers several advantages for creating digital 3D models. First, this process is relatively inexpensive and available to the public, with mobile phone and freeware solutions being sufficient. Second, photogrammetry creates authentic models by generating 3D images from digital photographs. This authenticity surpasses most computer models, which often simplify fine anatomical features. Third, photogrammetry does not damage physical models, nor rely on grayscale or cross-section data to create 3D models. Finally, photogrammetric models are digital and can therefore be distributed indefinitely and do not degrade over time (Petriceks et al., 2018).

The following basic rules must be observed when taking photos for photogrammetry:

1. Focusing and zooming - It is recommended to use a fixed focus lens, zoom lenses are less stable than fixed focal length lenses. If a zoom lens is used a constant focal length must be maintained.
2. Lighting - Affects shutter speed and ISO value. In the case of lower light intensity, it is advisable to increase it with artificial lighting. Proper lighting reduces noise and reduces the time it takes to take a picture. It is recommended not to use the flash due to inhomogeneous light distribution, possible reflection on the surface of the subject and the formation of shadows (Urbanová et al., 2015).
3. White Balance - White balance ensures accurate interpretation of the object's surface by correcting the chromaticity temperature of the light.
4. Photo Overlap - It is recommended that adjacent photos overlap by 20 to 50% to correct for optical system errors and identify tie points.
5. Shooting distance - depends on the dimensions of the subject and the lens used.
6. Scanning method (Luhmann et al., 2013).

These conditions can only be achieved when using professional equipment and in a controlled environment. Low-end cameras and mobile phones and limited lighting are very often used when creating models in the home environment.
Compared to acquisition of inanimate objects, capturing a 3D image of a human head is more critical; in fact, it is necessary to "freeze motion", that is, to avoid the breathing and movement effects. If images are captured at different moments, errors may occur due to large movements (change of head position) or minor movements (muscle activity, change of skin or hair surface) (L. Galantucci et al., 2009; L. M. Galantucci et al., 2013). Also, the head area is the part that is rich in hair (hair, tertiary hair), which can cause additional problems in modeling.
The aim of the paper is to determine the suitability of photogrammetry for human head scanning in a home environment with the minimum requirements for creating a 3D model (minimum number of images, position and lighting quality) and to determine the accuracy of scanning using the methodology and equipment for its subsequent use to obtain anthropometric data for other applications, e.g., technical orthopedics, education, medicine, etc. This article demonstrates the entire process of creating a 3D model through photogrammetry using only 1 camera by the walk-around method, highlighting the economic relevance of this method of creating 3D models.

Methodology of experiment

The pilot experiment was carried out on a living object, which was a young Caucasian woman who was acquainted with the conditions of the experiment and signed an informed consent. The experiment procedures involved non risk to participant therefore research ethics committee approval was not necessary. The object of measurement was the human head, the facial area and the brain part of the head. This area of the human body has been chosen for its wide range of sizes, textures, shapes and contours. The position of the subject's head during capturing is oriented in the Frankfurt horizontal. The subject's face without any make-up during the experiment and relaxed without significant facial expressions, the view is forward. The hair was adjusted so that it did not cover the face and so that the hairline and the ear were visible.

To evaluate the anthropometric dimensions of face in a locality with hair, it is necessary to remove it first.
Before scanning, it is recommended to remove from the scanned area all objects (jewelry, glasses, etc.) that could affect the scanning, data processing and evaluation.
A Canon EOS 70D digital SLR camera (Tokyo, Japan) with a Canon EF 50mm f1 / 4 USM lens (Tokyo, Japan) with a fixed focus was used to capture the subject. RealityCapture software (CapturingReality, Bratislava, Slovakia) was used to process the images and generate the 3D model. The measurement of the model created by photogrammetry was performed in GOM Inspect 2019 software (Carl Zeiss, Oberkochen, Germany) certified by PTB and NIST. The physical object was measured with a Somet caliper (Bílina, Czech Republic).
Capturing was performed outdoors with natural lighting (bright sunny day) and without artificial additional lighting. When taking craniofacial parameters, the subject sat on a 45 cm high chair and the position of his head was oriented in the Frankfurt horizontal. Due to the shape of the object and its texture, control points were placed on the irises of the eyes (Fig. 1). The face parts were photographed after the moment of person blinked. Throughout the shooting were used ISO 100, f8 aperture, and a shutter speed of 1/80.

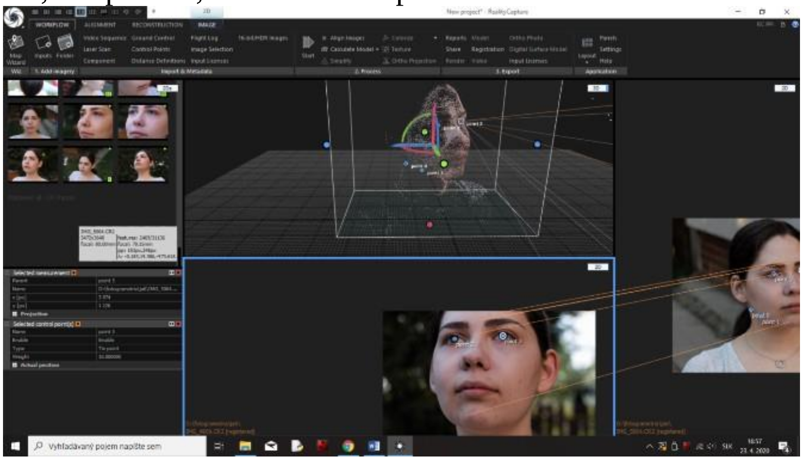

Fig. 1 Checkpoints located on the irises of eyes.

The person was photographed using the object walk-around method (Fig. 2). To ensure stability, the camera was placed on a tripod. The images were created in three levels. In each level, 4 images with a spacing of approximately 90° were taken around the circumference of the imaginary circle. In the first level, the axis of the camera was horizontal to the ground and the camera was at head level at a height of 120 cm. In the second level, the camera was 145 cm high and the camera axis was rotated 30° downwards. In the third level, the camera was 95 cm from the ground and the camera axis was moved 30° upwards. At the same time, the approximate distance of the camera to approximately 100 cm from the subject was maintained. In this way, 12 photographs of the head were taken. In order to capture the details, 6 more photos were taken, which focused on the ear area and more complex removable areas of the neck and chin.

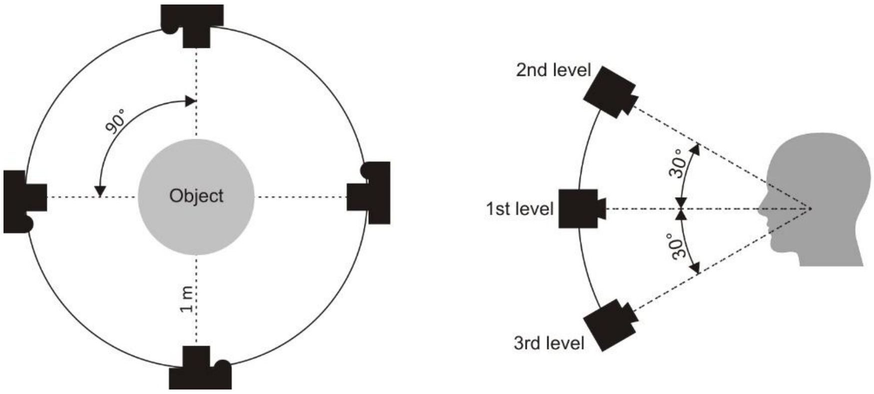

Fig. 2 Head scanning scheme, top view and side view.

Processing of acquired images

All acquired images were processed and visually evaluated in RealityCapture software, the resulting models were exported to *.obj format for measuring dimensions in GOM Suite.
The resulting model was created from 6,211,995 triangles and 3,106,561 vertices. Figure 3 on the left shows the non-textured STL head model in GOM Suite and the textured head model in RealityCapture. Different orientations of the used software are visible, in GOM Suite obtained surface is visible after merging individual images, in RealityCapture the surface structure is suppressed by the texture of the object.

Fig. 3 Display of STL model in GOM (left) and model in RealityCapture software (right).

When creating a textured model in RealityCapture software, there are visible hair reconstruction problems (Fig. 4 left), which the software cannot process as very thin objects. Other problematic parts of the model were the chin and neck area, where holes in the model were created due to insufficient number of overlapping points (Fig. 4 right). Other problems in the model are in the neck area, which were caused by incorrect alignment of the photos.

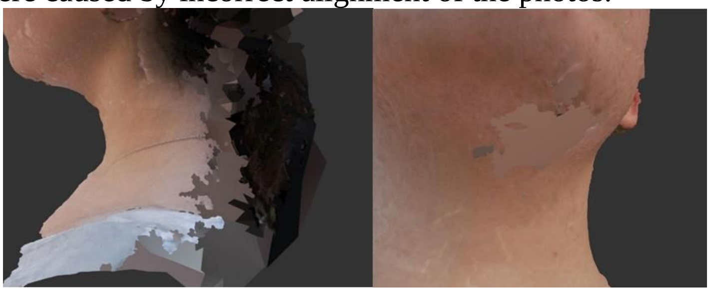

Fig. 4 Surface defects in hair, chin and neck.

In the GOM Suite software, minor defects can be seen all over the surface of the model without texture, resulting from the insufficient number of images and from the errors caused by composing photos or by calculating the geometry (filling the holes) when exporting from RealityCapture software. These errors are reflected in the uneven surface, mainly in the cheeks, chin and neck.

Dimensional analysis

On the basis of the obtained scan was created coordinate system, while the basic conditions for maintaining the position of the head were observed.
Measures of selected anthropometric head parameters (Fig. 5) (ear length and width, eye length, internal corners distance, head width, lower jaw width, head height, nose width and height) as reference measures were obtained manually using caliper to verify the accuracy of the scan. Manual measurements were performed three times after that arithmetic average were calculated. The model dimensions were taken using the GOM Suite 2019 software. Surface points were placed on the locations of individual anthropometric points using the "Surface Point" function. The direct distance between the individual points was measured using the "2-Point Distance" function (eg nose width, distance of the inner corners of the eyes), the other distances were measured in the direction of the individual axes and recorded in the table. Obtained values from physical measurements were compared with the values taken from the photogrammetric model.

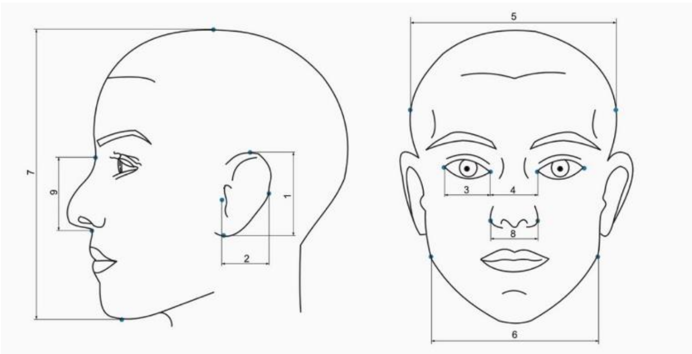

Fig. 5 Selected anthropometric measures of the head.

Results

Table 1 shows the differences between the physical object (reference model) and the 3D model. The differences are calculated as subtraction of dimensions measured on 3D model and dimensions measured manually.

Tab. 1 Difference values of anthropometric parameters of the head.

Measured dimension		Difference (mm)	
		Right	Left
1	Ear length	0.102	0.516
2	Ear width	0.278	0.456
3	Eye length	0.232	–0.259
4	Intercanthal	0.468	
5	Head width	0.835	
6	Mandibular width	–0.951	
7	Head height	1.813	
8	Nose width	–0.820	
9	Nose height	0.924	

The results show that the values obtained from the 3D model differ from the reference values from 0.1 to 1.8 mm. The difference between the values takes on a positive and a negative sign, so it is not possible to claim that the model is neither reduced nor enlarged. Minor deviations came out on the right side of face, the left side is affected by the reconstruction of the surface, where the surrounding hair caused the surface to deform. Dimensions at head width and height could be affected by hair, nose width and height, lower jaw width could be affected by soft tissues or inaccurate identification of anthropometric points.

Discussion

A 3D model of the head was produced using the walk-around method, which presents the disadvantage of increasing labor-intensiveness, since photo equipment must be moved around while maintaining the distance between it and the object. In this way, the object remains stationary, considerably reducing the risk of movement, but it increases the capturing time, that can lead to possibility of increasing the movement risk. To achieve higher quality and resolution of the model and textures, the object could be rotated. By rotating the subject (for example, sitting on a swivel chair), the risk of the subject moving is increased, but the capturing time decreases. However, this is a more expensive solution, as it requires a monochrome background, tripod, turntable and additional lighting.
In practice, the traditional method of direct measurement of anthropometric parameters is still the most used. Measurements done by direct method are simple, noninvasive, and do not require expensive equipment (Urbanová et al., 2015). Certainly, a benefit of this technique is the possibility of palpating individual anthropometric points, but soft tissue compression can cause deviations as well. Inconvenience, time consumption, and experience are disadvantages. On the other hand, measuring with software has the advantage of being non-contact, it nevertheless requires experience, and its major disadvantage is the more challenging measurement of anthropometric points. There is a partial solution in the form of manual palpation and labeling on the skin, which is then followed by scanning.
To improve the connection of the images, it is advantageous to use morphological features on the face (checkpoints). A checkpoint is chosen according to the morphology of the face and the unique identification points. Studies often use the pupil as reference points. In the case of a darker iris, their identification is complicated. For this reason, irises have been chosen as reference points for our purposes. The disadvantage of choosing pupils or irises is their response to environmental stimuli (movement). The solution would be to choose these points on the facial skin.
The control of mimic movements and breathing is essential when scanning the head, as they can significantly affect the composition of individual images. The biggest problem is capturing and then creating a model from an area with hair, because defects on the model and textures occur in these places. The solution could be to fix the hair with a hat or hair net.
Based on 3D scanning experiences of children’s faces photogrammetry is more suitable method for scanning children since the flash is not used because of sufficient lighting and child does not respond to flicker as it is at most 3D scanners. Additionally, this scan does not take place in a dark closed environment like some 3D full-body scanners. The above information indicates the suitability of this method for people with various diseases, where the use of 3D scanners is limiting.

Conclusion

The living object model provided an effective interpretation of the surface and texture of the subject's face.

The data were processed in the RealityCapture software, where the images were combined into one object. The 3D model with texture was created and the data was exported for measurement in the GOM Suite. Empty areas were showed during processing, due to low number of images (12 photos). For this reason. another 6 images were taken from the problem areas. filling in the empty areas and improving the quality of the details. In order to improve the composition of the images, the irises of the eyes have been designated as control points, but it is necessary to ensure their stability by focusing on the selected point.
An anthropometric map was used to measure dimensions in the GOM Suite program. According to the results, the largest deviation is 1.8 mm compared to the manual measurement.
The differences between manual measurement and the measurement made on the 3D model may be related to soft tissue compression during manual measurement, as well as the ambiguous determination of anthropometric points on the model. There is less than 2 mm difference between the measurements, which is sufficient for most possible uses.
Based on the experience of creating a model using photogrammetry and the results of measurements, photogrammetry appears to be an effective tool for digitizing living objects and performing measurements on the model, provided that the conditions and optimization of imaging are observed. As a bonus, the person can have their eyes open when being photographed, thus capturing the color of their iris. The output model is sufficiently detailed and the obtained surface texture allows the model to be utilized for numerous purposes (medicine, criminology, anthropology, technical orthopedics and others).
The photogrammetric method can be used to scan various parts of the body. However, when it comes to shooting larger areas or the entire figure, the required equipment becomes quite complex.

Review process: peer reviewed process by two reviewers.

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DIGITAL ENGINEERING ELEMENTS APPLICATION IN INNOVATION AND OPTIMIZATION OF PRODUCTION FLOWS

Peter TREBUŇA – Richard DUDA – Tomáš ŠVANTNER

Abstract: The main objective of the presented article is to propose a comprehensive methodology for designing a new type of production system oriented to mass customization with the support of digital engineering elements in line with the RIS3 smart specialization strategy. The goal of the project is to create a unique methodology that will use digital engineering tools in design, innovation and optimization of production flows of existing types of industrial production. The main support tools for ensuring quality information collection will be the state-of-the-art software tools, which we have at the research site and allow for verification of corrections from the obtained data.
Keywords: digital engineering, optimization, modelling, simulation, optimization.

Introduction

The results of the research project will be developed and applied initially in the design of innovations and optimization of production flows in laboratory conditions of the department responsible for the Institute of Management, industrial and digital engineering, as well as in the industrial practice of companies Howe Slovakia Ltd, SHP Slavošovce, joint stock company, GETRAG FORD Transmissions Slovakia Ltd , SHP Harmanec, joint stock company, Embraco Slovakia Ltd, RYBA Košice Ltd. and TAURIS, joint stock company. and others.

Research Subject

The methodology of the project solution consisted of four stages: 1. analysis of the current state developed on the basis of the experience of the team of solvers in the field of designs and modification of processes in heterogeneous industrial enterprises, 2. design of application solutions for real and simulation systems aimed at defining acceptability parameters for simulation models. , 3. programming and testing of the proposed system and application functionalities of the methodology with the help of test scenarios implemented on the basis of the experience of the team of researchers, 4. integration, the result of which was the incorporation of researched relationships defined on the basis of selected parameters into designed simulation models and their verification in laboratory and industrial practice conditions.

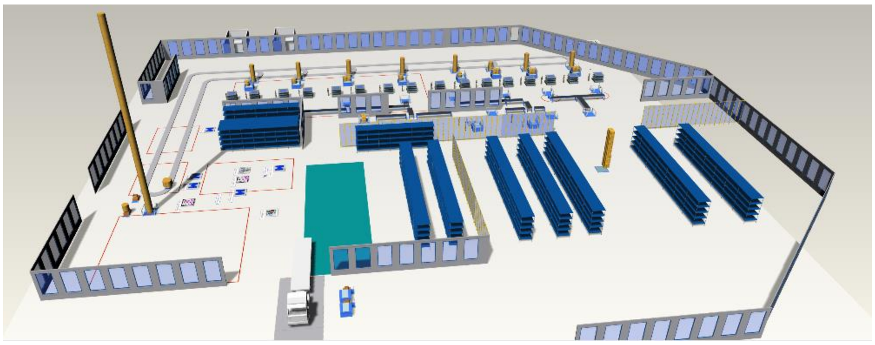

Fig. 1 Proposal for a solution to the expansion of existing production using digitization methods and techniques

Aim of the Research

The main goal of the presented project was to propose a complex methodology for designing a new type of production system with the support of digital engineering elements in accordance with the strategy of intelligent specialization RIS3. A unique methodology was created that uses digital engineering tools in the field of designing, innovating and optimizing production flows of existing types of industrial production.

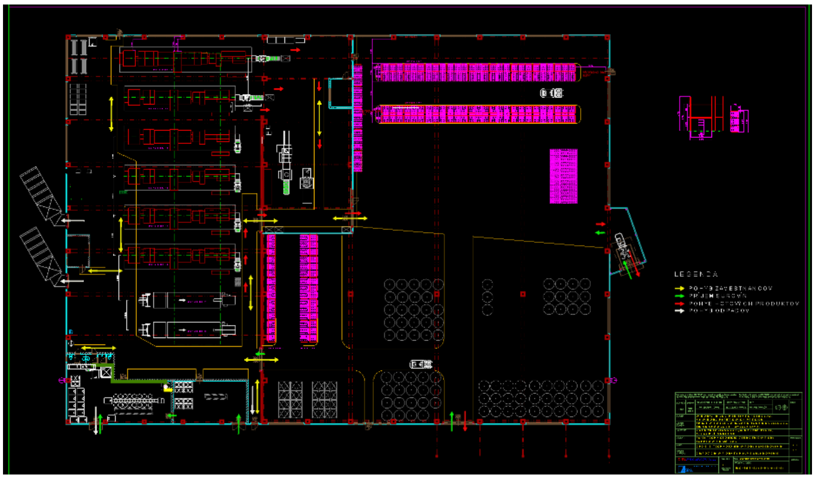

Fig. 2 Digital simulation model of the company's production space (layout)

The main supporting tools for ensuring high-quality information collection were the most modern software tools that we have at the research workplace and enabled the verification of corrections from the obtained data.

Achieved Results

The fundamental result of the presented project was the creation of a unique methodology that can be used in a virtual environment during the transition to digital production supported by the application of the latest software.

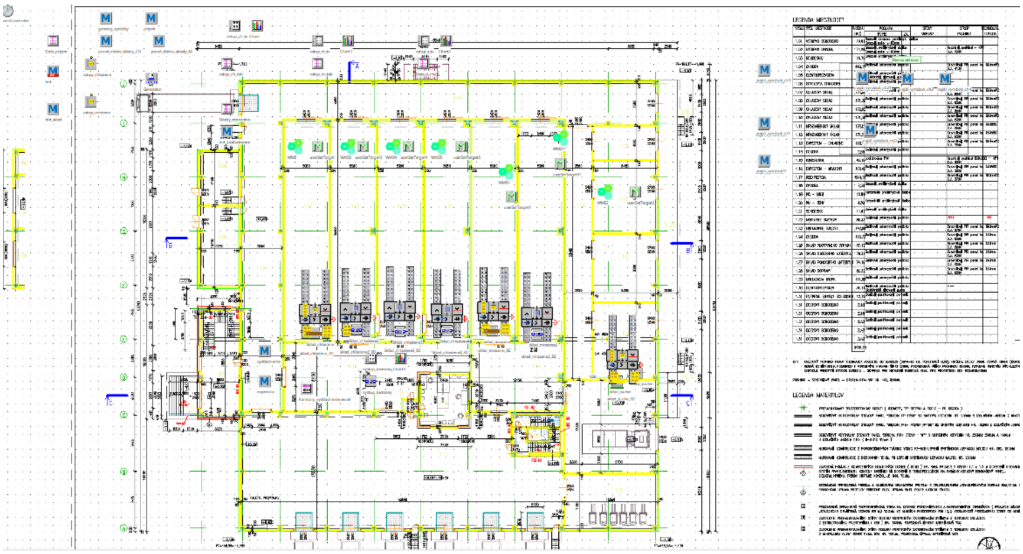

Fig. 3 2D simulation model of the proposed warehouse space

A number of shortcomings were identified, which can either be parameterized or corrected by introducing change management in leaps and bounds, or by reengineering existing business activities by proposing a complex methodology for designing a new production system, which integrates tools such as conventional modeling of changes in production parameters, simulation of production flows, animation of change proceedings, virtual, augmented reality and reverse engineering.

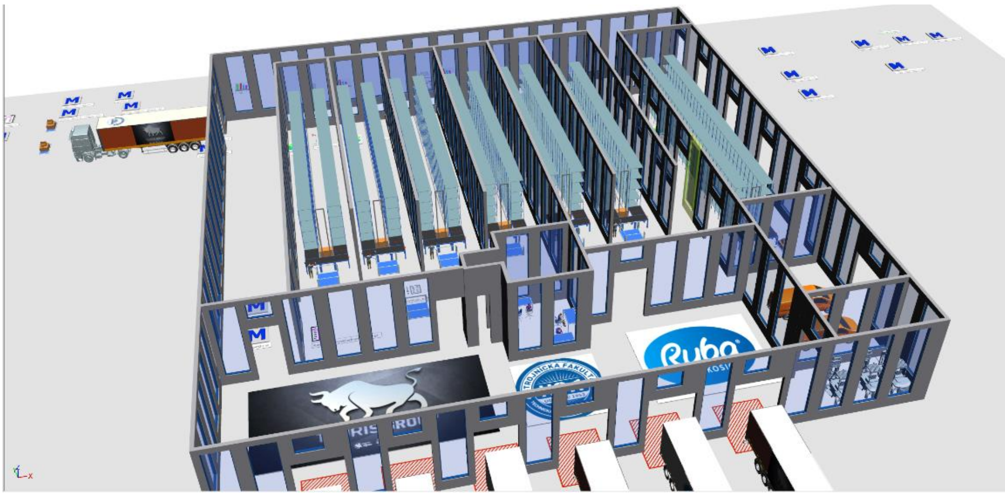

Fig. 4 3D simulation model of the proposed warehouse space

This enabled the verification of corrections from the obtained data and the subsequent creation of a methodology that is often absent in the decision-making processes of organizations in Slovakia, but also abroad. In the past period, this workplace underwent a radical transformation in response to the demands and challenges of industrial practice, which was ultimately reflected not only in the creation of new and strengthening of existing ties with enterprises of industrial practice, but also in the creation of networks in the aforementioned area with scientific institutions at home and abroad.

Benefits for Practise

A more fundamental influence on the creation of a complex methodology was processed in the form of digital, virtual and 3D models of the investigated workplaces. The conception of this digital model and all its attributes was extremely important for the verification and comparison of the so far explored links of digital interactions within the enterprise processes of engineering production, ultimately leading to the creation of virtual manuals and the analysis of production and work spaces with all their parameters that can be modified according to the current requirements of industrial practice.

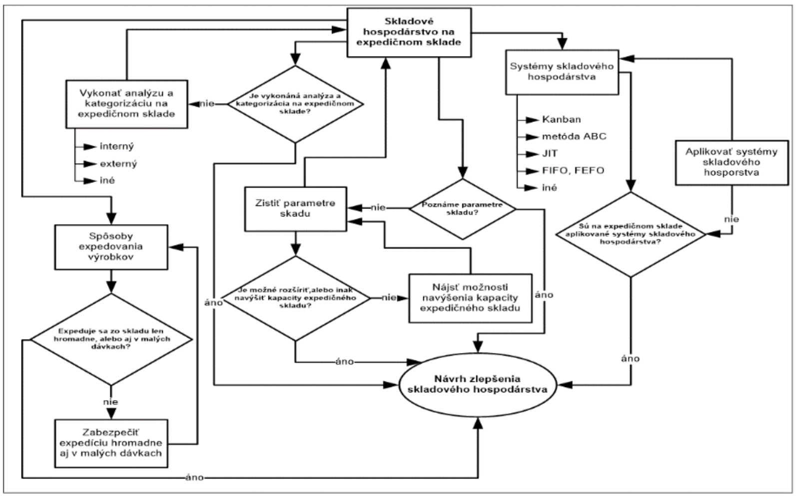

Fig. 5 Algorithm for improving warehouse management in a shipping warehouse

A complex methodology for optimizing the production line and material flow was developed using the Tecnomatix Plant Simulation and Process Simulate software module. The mentioned methodology was built on the basis of a simulation task for the company Eco-bags, s.r.o., the design of a digital simulation model of the finished product warehouse of the company Calmar (Tauris Group, a.s.), the construction of which is currently underway according to the proposed solution by the responsible researcher and selected members of the research team as well as digitized model of the PAIC SjF TUKE workplace. The first method was a digital virtual tour through a virtual headset according to the exact data obtained from the proposed floor plan solution, the second was a capacity calculation of the status of finished and work-in-progress production, which enabled reconfiguration based on the scientific and research requirements of the project itself. The modularity of the solution allows the reconfiguration of the input parameters according to the client's requirements.

Conclusion

The presented project supports the automation and digitization of production processes, enabling the development of cyber-physical systems (CBR) with focus on production and logistics processes. Other areas of project utilization are connected to increasing of process productivity, increasing of stability, and reducing of costs. The project reflects a long-term vision of the production process direction and prepares conditions for Slovakia to be perceived as a country actively approaching the research of new progressive areas in automation and digitization.
Interaction of production facilities (workstations, lines and businesses) and simulation models of devices will bring new insights into the dynamics of production and logistics processes. Analyzes that will be performed on a created cyber-physical system (interconnected physical devices) can contribute to the emergence of new production and logistics strategies in industry. Achieving the main goal of the project will only be possible with the synergy of research capacities and years of experience of the applicant in the field of simulation technologies. Within the project, research is also carried out on secondary issues of deployment of digital engineering systems.

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Review process: peer reviewed process by two reviewers.

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ANALYSIS OF PRODUCTION PROCESSES IN TESTBED 4.0

Jozef TROJAN – Marek KLIMENT – Matúš MATISCSÁK

Abstract: In the presented article, we thoroughly analyze the individual production processes that take place in TestBed 4.0. We will divide them into two main parts: pre-production processes and production processes, which contain other sub-processes necessary for the smooth process of handing over the order to the customer.
Keywords: process analysis, TestBed 4.0, competitiveness

Introduction

In industry, the possibilities of how to improve production processes are increasingly addressed, which creates the need to analyze the individual parts that make up the production process, for which workplaces and laboratories with integrated elements from Industry 4.0 are used. Thanks to the analysis of these processes, the time it takes for products to reach the market is shortened and, thanks to this, the diversification of the company's offer increases.

TestBed 4.0 responds to changes and market demands and brings the possibility to create intelligent industrial enterprises that are fully automated and constantly optimized thanks to the possibility of connecting production equipment with digital models. The possibilities of implementing innovative designs offered by TestBed 4.0 contribute to ensuring the competitiveness of Slovak industrial enterprises within the European market.

Division of processes

In industrial enterprises, a large number of processes are carried out, which are necessary for the correct course of production and ensuring the delivery of the ordered product to the customer on the specified dates. Such processes take place gradually, with a certain continuity. Therefore, in order to achieve high performance of the company, it is necessary to organize and control these processes effectively in order to ensure high production efficiency in the company at the lowest possible costs.

We divide these processes into two main parts:

<u>Pre-production processes, which include processes such as:</u>

- Communication with customers.
- Creating an offer for the customer.
- Order acceptance.
- Construction processing.
- Processing of production technology.
- Purchase of necessary material for production.

<u>The production processes include:</u>

- Planning of production.
- Production management.
- Shipping of the finished product.

Communication with the customer about a potential order

This process consists in the request of the customer who asks for the preparation of an offer, which includes the price, the delivery date, the conditions under which the industrial enterprise is able to deliver the goods. The customer also specifies the number of necessary manufactured pieces. An industrial company tries to develop an offer so that it is profitable and at the same time the price must not discourage the customer, because the customer sends the request to several companies. The data about the shipment will be taken over by the business center (Fig. 1) of the company, which will record and store it. Based on these documents, he instructs the preparation of an offer for the customer.

Fig. 1 Workplace for product data management

Creating an offer for the customer

The offer for the customer includes the price, terms of delivery of the products and the date of delivery of the goods. The offer must be processed in such a way that the company receives more funds from the order than the costs associated with the material, the price of labor, the operation of machines, energy, the use of company premises and other production costs. He has to design the offer in such a way that it is profitable and he has to take care of the delivery of the goods on time and to the agreed place specified by the customer. This whole process must be prepared in advance and correctly, which can sometimes be difficult. The use of PLM software and their databases make this process easier for us, because they allow us to compare a new order with a previous order of a similar kind and, based on this information, determine the time required for production.

The price offer is prepared by the business center of the company, which collects data from:

• Construction departments
- sells his statement on the construction of the product and its complexity.

• Technology departments
- sells his estimates for the price of material consumption, work, or cooperation.

• In stock
- sells price estimates for materials and cooperation.

After incorporating all the data, the business center adds a corporate margin and sends the prepared offer to the customer.

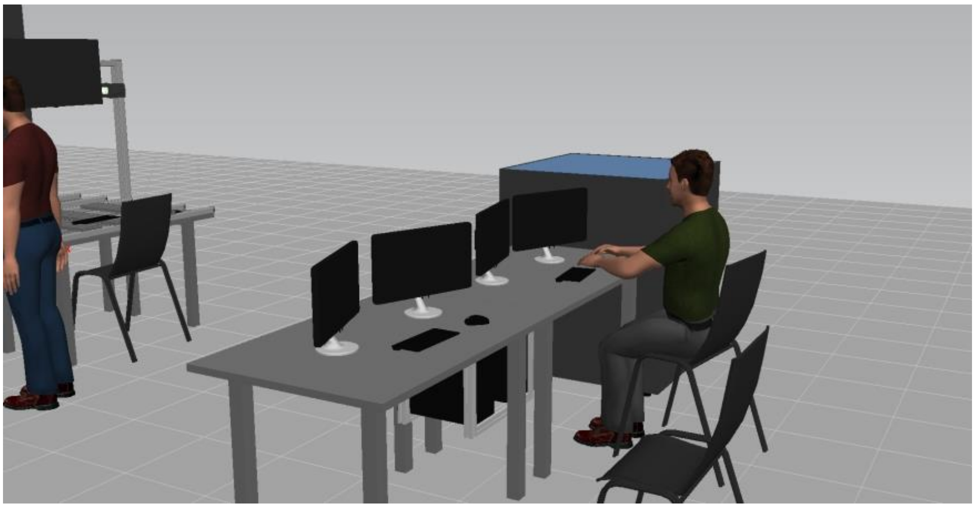

Fig. 2 Price offer processing workplace

Order acceptance

The customer receives price offers and considers the most suitable one, prepares an order and sends it to the chosen company. The customer will reject other offers. On the basis of the received order, ordering contract, the company issues an instruction to start the preparatory processes of production.
The order is processed by the business center of the company, which registers it and instructs individual departments to prepare complete documentation for production planning.

Construction department

He is responsible for the correct construction of the product and the verification of the correct functionality (Fig. 3), the development of technological documentation and the creation of the parts list for the given product.

Fig. 3 Workplace for structural design verification

Technological department

He is in charge of developing the technological process of production for the given product - estimation of material consumption, or proposes cooperations.

Warehouse

The role of the warehouse is to ensure continuous and smooth operation in terms of material security, it is responsible for ordering missing material and ordering cooperation.
After all the details have been worked out, the documentation is sold to the production planning department.

Planning of production

This process has the task of designing an optimal production plan (Fig. 4) so that all orders are produced at the agreed time, at the same time it ensures that production is not too complicated and everything is produced as quickly as possible, with the highest utilization of people and machines in the company.
The production planning section is responsible for creating the plan, which takes care of the effective implementation of technological processes into the current production plan and takes into account across the entire company:
- Material stock.
- Cooperation with other companies.
- Priority orders.
- Order delivery date.
- Production capacities.

The production plan is subsequently taken over by the production management department.

Fig. 4 Workplace optimization of production procedures

Production management

The production management section is responsible for adapting the production plan to the current state of production. Production plans are made ahead of time. When creating a production plan, production planners cannot foresee situations that may arise in production, for example, machine failure, lack of material, absence of a production employee. Production management must respond adequately to these deficiencies and adjust the production plan in cooperation with the production planner in order to ensure the smoothness of production processes and information flow (Fig. 5) throughout the company. The production manager has the task of correctly assigning work to individual sections in production, at the same time he is also responsible for issuing the material necessary for production and solves the most common problems occurring in production.

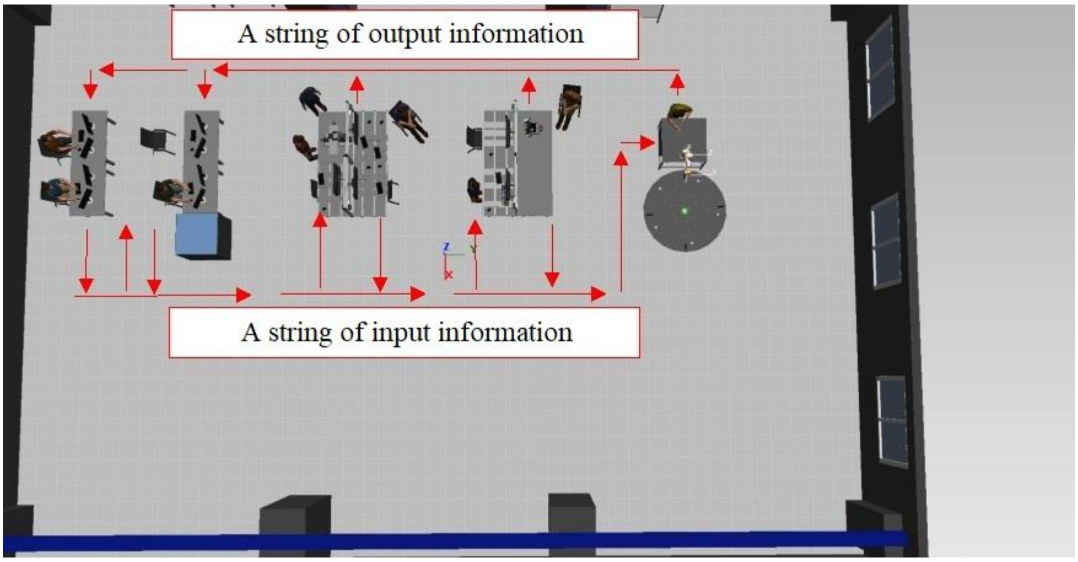

Fig. 5 Information flows within workstations

Shipping of the finished product

The shipment of goods is handled by a warehouse employee who, on the basis of the shipping document, which determines what and when needs to be sent, prepares the finished products and gives instructions for the preparation of the necessary shipping materials, for example:

- Billing sheet.
- Delivery document.
- CRM confirmation.

This process ends with the final shipment of the product to the customer according to the agreed terms.

Conclusion

In TestBed 4.0, various applications and technologies are combined for the development, verification of functionality and compatibility of new solutions in the digital environment and in interaction with the most modern available technologies. The workplace is also a unique research environment for the development and testing of innovative solutions for advanced and fully integrated industrial production and processes for smart factories. Thanks to the flexible connection of universal production tools and a refined control system, in Testbed 4.0 it is possible to use the same means for the implementation of various operations, which just need to be configured according to the needs of individual assignments.

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USE OF LINEAR PROGRAMMING IN THE PRODUCTION PROCESS

Gabriela IŽARÍKOVÁ – Anton HOVANA

Abstract: Nowadays, a prosperity of companies mainly depends on timely and correct decision-making on the way to achieve the greatest possible efficiency of work in a production process and in service activities as well. One of the possibilities for achieving more efficient production is an application of operational analysis methods. Mathematical programming methods, which allow transforming real processes into mathematical models, are the most frequently used methods for optimizing production processes. Linear programming plays an important role in mathematical programming. The contribution is devoted to the application of linear programming in the production process with the aim of maximizing profit.
Keywords: linear programming, simplex method, optimal solution

Introduction

Currently, in many cases, there is very strong competition on the market. Price companies use a price as a fighting tool. Price competition is about strengthening a position on the market with and intention of destroying and opponent. It means that manufacturers voluntarily reduce the price of goods which attracts a consumer and they try to gain a share of the market. Finally, their profit will be higher. Furthermore, non-price competition is based on acquiring a customer by methods other than price. It can be done by increasing a quality of production, expanding sales conditions, using advertising, design and service. Moreover, the company's brand and tradition can play a crucial role in that way. Trade competition forces producers to behave efficiently, to find ways for achieving maximum performance (profit) with limited resources.

An optimization of resources is required in every aspect of our lives because we are limited by time and cost and therefore we need to take the maximum out of them. Today, every aspect of the business world requires optimization, from manufacturing to resolving supply chain issues to stay competitive.

Trade entities must look for different models, algorithms that will help them to achieve the most efficient production. One of the possibilities is the application of operational analysis methods. The subject of operational analysis research is study and analysis of operations and processes that take place or are planned in a certain organizational unit, while the study and analysis of these operations is most often carried out using mathematical modeling.

Mathematical Programming

Mathematical programming of economic phenomena and processes is the important tool for rationalizing the management activities of companies which is amplified using computer technology and automated control systems. Today, solutions using mathematical models affect various areas: planning, economic analysis, forecasting and management. The problems solved in practice are diverse and it is possible to use and apply different modeling techniques and different types of models and methods when solving them.

Mathematical programming methods are among the frequently used methods for optimizing production and other decision-making processes, which allow transforming real processes into mathematical models. Mathematical programming represents a set of optimization methods allowing selecting the optimal solution from the set of admissible solutions. Linear programming plays the important role in mathematical programming.

The goals of the models depend on the process itself, they are optimization (maximization or minimization) criteria: optimization of the production plan, optimal deployment of machine sets, optimization of price and costs, optimization of the order size, optimization of the goods delivery plan, optimization of the location of machines, selection of suppliers of raw materials, semi-finished products, of products, localization of new production capacities, maximization of profit, maximization of productivity, maximization of equipment efficiency, maximization of profitability, maximization of the quantity of transported goods, minimization of production costs, minimization of labor costs, minimization of waste, minimization of costs for transport.

Within the processes, there are conditions and restrictions under which the process is supposed to function (limiting conditions): material resources, financial resources, capacities of production facilities, capacities of labor forces, transport capacities, capacities of suppliers, capacities of warehouses, customer requirements, sales possibilities, scheduling of workers to work shifts, lifetime of food and equipment, and others.

We will describe an orderly sequence of steps that can be followed for a systematic formulation, solution, and implementation of the mathematical-programming model. These steps could be applied to the development of any management-science model. Although the practical applications of mathematical programming cover a broad range of problems, it is possible to distinguish five general stages that the solution of any mathematical-programming problem should follow.

- Formulating the model.
- Gathering the data.
- Obtaining an optimal solution.
- Applying sensitivity analysis.
- Testing and implementing the solution.

Linear programming is a part of mathematical programming, the subject of which is the representation of a certain economic reality in order to find the best solution under certain limiting conditions. From a mathematical point of view, it is about solving problems for bound extrema of functions in several variables. In the case of linear programming, it is about finding the extrema of linear functions, while the boundary conditions (equations, inequalities) are also linear. The basic contents of linear programming are tasks with one objective function.

Linear programming problems

Mathematical models of linear programming tasks are linear, deterministic and static. This means that all mathematical relationships in the model are linear functions, input and output data are constants, the model is formulated for a specific period, and its results do not take into account changes over time.

A linear programming problem, LP problem for short, consists of decision variables, the objective function, constraints and non-negative restrictions. The decision variables x_j where $j = 1, 2, \Lambda\ n,$ decide the output of the LP problem and represent the final solution. The objective function z is the linear function that needs to be optimized (maximized or minimized) to get the solution. The constraints are imposed on the decision variables to limit their value. The decision variables must always have a non-negative value which is given by the non-negative restrictions. The general form of the LP problem is given below:

Objective function: $z = c_1 x_1 + c_2 x_2 + \Lambda\ c_n x_n$ optimization (maximized, minimized)

Constraints:

$$\begin{cases} a_{11}x_1 + a_{12}x_2 + \Lambda\ a_{1n}x_n = b_1 \\ a_{21}x_1 + a_{22}x_2 + \Lambda\ a_{2n}x_n = b_2 \\ \Lambda \quad \Lambda = \Lambda \\ a_{m1}x_1 + a_{m2}x_2 + \Lambda\ a_{mn}x_n = b_m \end{cases}$$

Non-negative restrictions: $x_j \geq 0$

- x_j decision variables $j = 1, 2, \Lambda\ n,$
- a_{ij} constraint coefficients (also called the matrix coefficients) $i = 1, 2, \Lambda\ m,$ $j = 1, 2, \Lambda\ n,$
- b_i righthand side coefficients of the mathematical-programming model $i = 1, 2, \Lambda\ m,$
- c_j coefficients of the objective function $j = 1, 2, \Lambda\ n,$.

Using linear programming, it is possible to determine optimal solutions to a large group of practical decision-making problems. The most important part of solving linear programming problem is to formulate the problem using the given data at first. The steps to solve linear programming problems are given below:

1. Defining the economic model - verbal entry and formulation of the goal of the solution. Formalization of the economic model - entry of variables, factors and relationships among them into a table. Identify the decision variables.
2. Create a mathematical model - formulate the objective function, check whether the function needs to be minimized or maximized. Write down the constraints. Ensure that the decision variables are greater than or equal to 0, (Non-negative restraint).
3. Solve the linear programming problem using either the simplex or graphical method.

Simplex method

The Simplex method is an algorithm solving linear programming problems presented in a standard form is the task of minimizing (maximizing) the objective function:

$$\mathrm{f}(\mathrm{x}_1, \mathrm{x}_2, \ldots.) = z = c_1x_1 + c_2x_2 + \Lambda\ c_nx_n.$$

Its general algorithm is shown in Fig. 1. The Simplex method is a cyclic iterative procedure that allows determining the optimal solution after a finite number of iterations.

The Simplex method is a search procedure that sifts through the set of basic feasible solutions, one at a time, until the optimal basic admissible solution (whenever it exists) is identified.

In each iteration, the admissible basic solution can be obtained, which is tested to be optimal. If the solution is optimal, the calculation is terminated, if not, the next feasible basic solution is examined. With the Simplex method, after the finite number of steps, the optimal solution is determined, or it is found that the optimal solution does not exist.

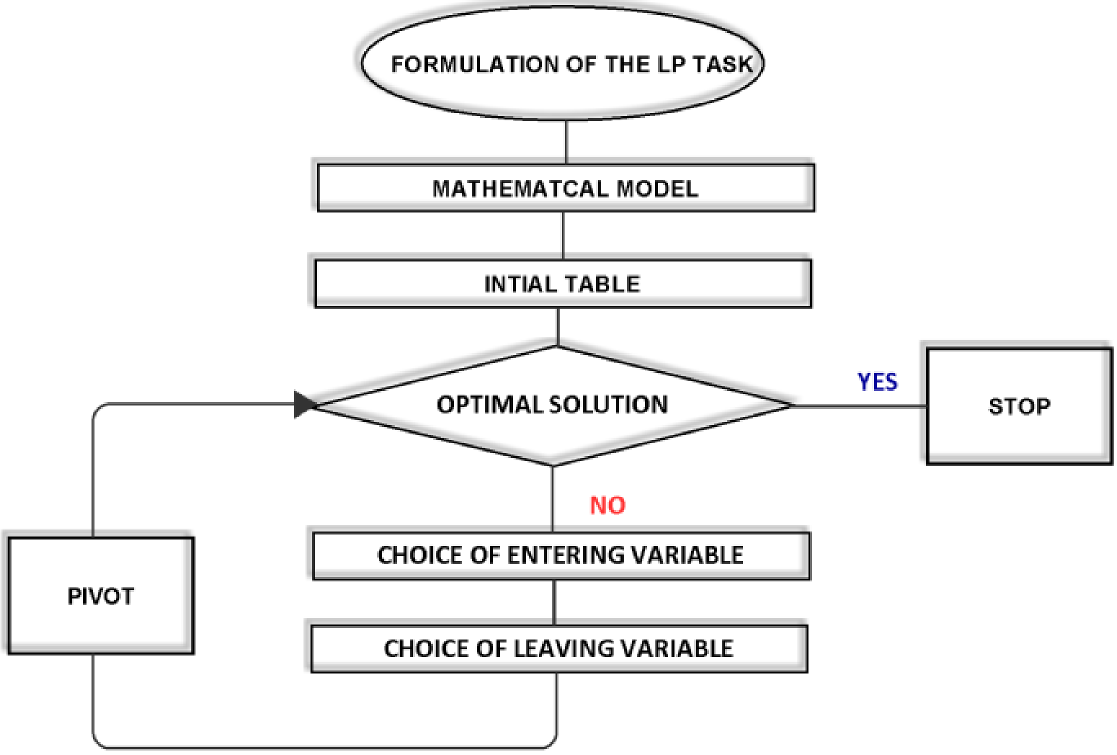


Fig 1. General algorithm of the Simplex method

The algorithm was discovered by George Dantzig (1914-2005) who is known as the father of linear programming.

Basically, there are many different linear programming problems but we will deal with Manufacturing Problems in this article. Manufacturing problem deals with the number of units that should be produced or sold in order to maximize profits when each product requires fixed manpower, machine hours and raw materials. It is used to determine the transportation schedule to find the cheapest way of transporting a product from factories situated at different locations to different markets.

Simpler problems of linear programming with two variables can advantageously be solved graphically. The graphic representation of a linear function of two variables in a plane is a straight line, in three-dimensional space it represents a linear function of three variables. Finding the optimal solution to a linear programming problem with two variables is graphically illustrated by the following example.

Mathematical model of the task (maximize the value under the constraints):

$$4x + 5y \quad \rightarrow \quad MAX$$

$$3x + 8y = 32\,, \qquad x + 8y = 24\,, \qquad x + y = 8$$

$$x \geq 0, \quad y \geq 0$$

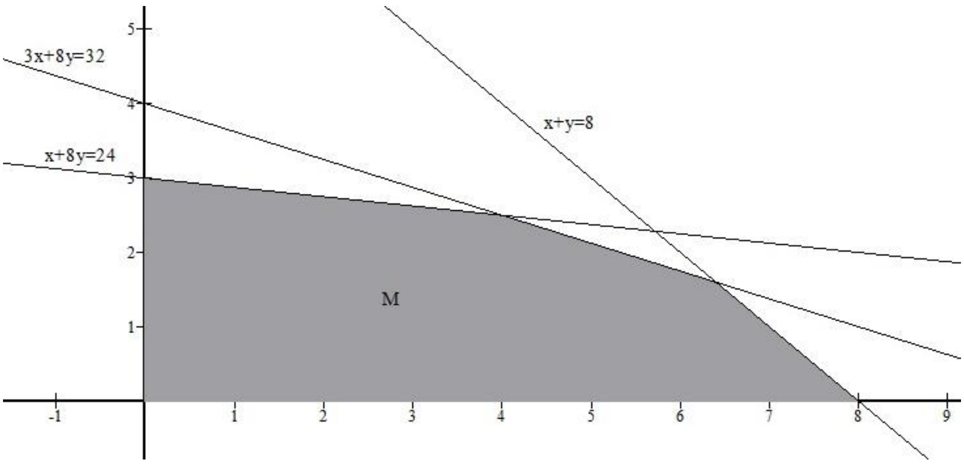


Fig 2. Set of admissible solutions

The set of admissible solutions is shown in Fig. 2 and the optimal solution of the task is in Fig. 3. The objective function reaches its maximum at the point [6.4, 1.6] and the value of the objective function at this point is $4x + 5y = 33.6$, the problem has only one optimal solution. The graphic solution can be verified by exact software calculation, Fig. 4.

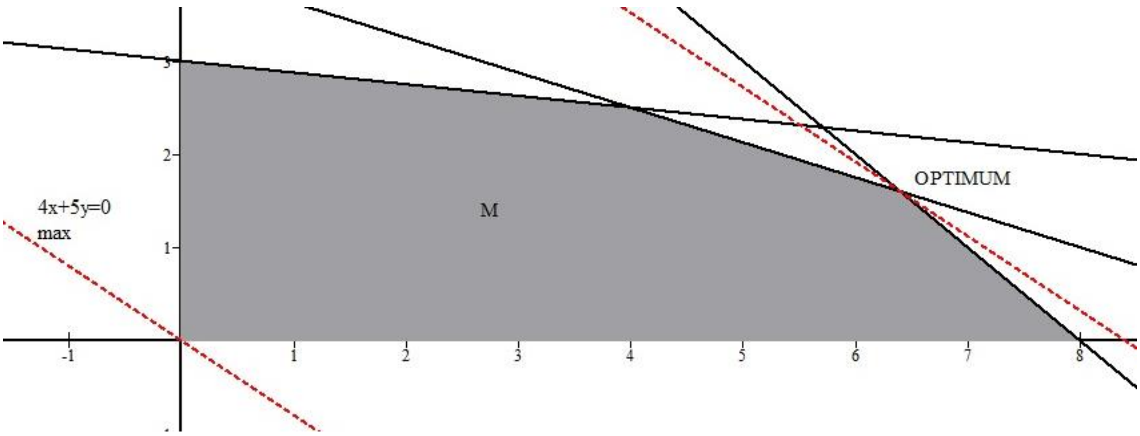


Fig 3. Optimal solution

The shortcoming of the graphic method is the fact that it is only applicable for solving problems with two variables. In the case of three variables, the three-dimensional graph display would not be clear. In practice, larger tasks with a significantly larger number of variables and boundary conditions are usually solved, the solution of which can also be found using computational techniques, such as Solver is a Microsoft Excel add-in program, program R and other.

In Excel, you can use Solver to find an optimal value (maximum or minimum, or a certain value) for a formula in one cell called the objective cell, subject to certain constraints or limits, on the values of other formula cells on the worksheet. This means that the Solver works with a group of cells called decision variables that are used in computing the formulas in the objective and constraint cells. Solver adjusts the values in the decision variable cells to satisfy the limits on constraint cells and produce the result you want for the objective cell.

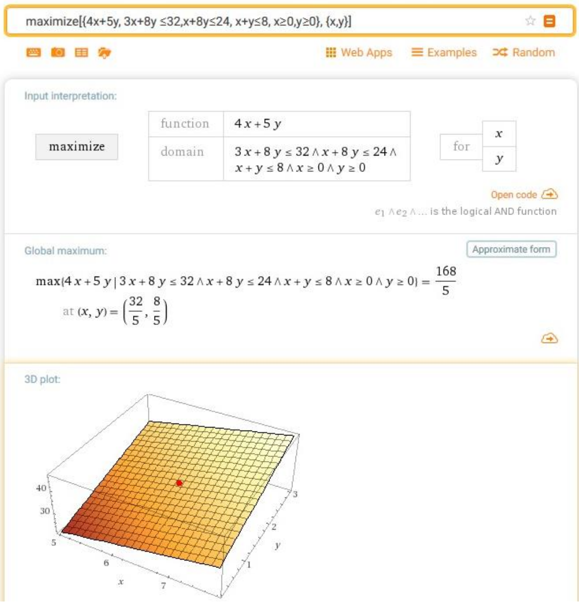
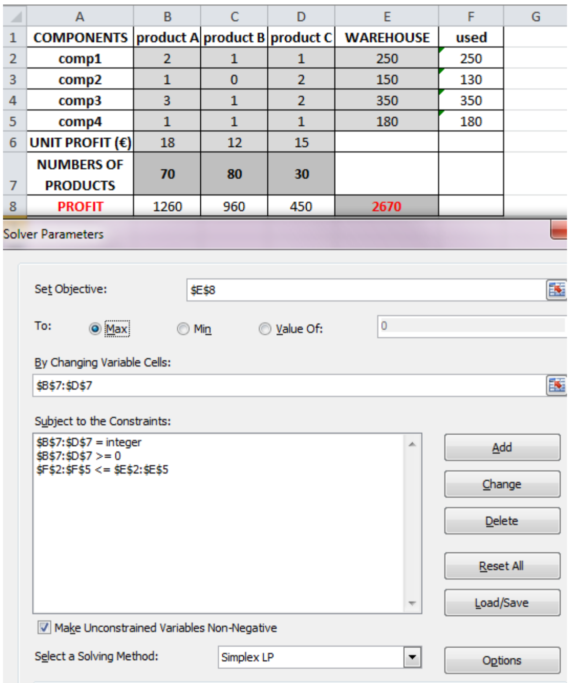


Fig 4. Objective function and optimal solution using software

You can use Solver to find optimal solutions for diverse problems such as determining the monthly product mix for a manufacturing components that maximizes the profitability.

Production problem: The requirements are known - the amount and combinations of components that are needed for the production of individual products, as well as the capacity, how many components are in warehouse. The unit profit of the products is also known. The task is to find out how many pieces of individual products need to be produced in order to maximize profit.



	A	B	C	D	E	F	G
1	COMPONENTS	product A	product B	product C	WAREHOUSE	used	
2	comp1	2	1	1	250	250	
3	comp2	1	0	2	150	130	
4	comp3	3	1	2	350	350	
5	comp4	1	1	1	180	180	
6	UNIT PROFIT (€)	18	12	15			
7	NUMBERS OF PRODUCTS	70	80	30			
8	PROFIT	1260	960	450	2670		

Fig 5. Solving production problem by the Solver

When creating a model, it is important to know:

- what is optimized – it is the number of products that need to be produced,
- what is the goal - profit maximization, (the goal can be maximization or minimization of any output value),
- constraints – these are the capacities of the components (that is, the number of used components cannot be greater than the actual number that is available).

The constraints in the Solver setting include the non-negativity condition, which states that a negative number of products cannot be produced, and the integer condition, according to which the number of produced products must be a whole number.

The recording of known values, the creation of a table in Excel and the setting of the Solver are shown in Fig. 5.

The optimal solution under the given conditions is the production of 70 pcs of the A type, 80 pcs of the type B and 30 pcs of the type C. A maximum profit of 2670 € will be achieved.

Conclusion

In the production process, decision-making problems are often solved, in which possible variants are assessed from different points of view, experiments are carried out and the most advantageous solutions are sought. Many of these problems can be effectively solved with the mathematical tools. In this paper, the simplex method is applied to determine the maximum profit. Most of the problems in the production process can be converted to the linear programming task and solved here using the simplex method.

Acknowledgement

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DESIGN OF A THREE-WHEELED UNIT FOR THE MANUFACTURING INDUSTRY

Juraj KOVÁČ – Peter MALEGA – Jozef SVETLÍK – Michał SĄSIADEK

Abstract: The article describes the design of an intelligent three-wheeled unit. The three-wheeled unit is to be used in production halls for the transport of people, as well as for the transport of materials, parts necessary for the provision of production processes. One of the main advantages of the three-wheel unit is to be the smaller dimensions of the three-wheel unit and also the possibility of attaching a trailer, which implies the need for a sufficiently strong drive and also a more robust construction. The drive of the three-wheel drive unit will be provided by an electric motor. Another advantage is the possibility to communicate with the equipment in the production hall using wireless technology and the requirements of the production equipment, which will be displayed using an application on a display device - a tablet.

Keywords: Three-wheel drive, manufacturing industry, electric drive.

Introduction

Man is an integral part of the manipulation process, but he is limited by his limits. Technology helps him to exceed these limits several times over. Industrial trucks are among the most commonly used handling equipment. These are road or rail vehicles, with or without motor drive, designed for transport, handling, loading and storage operations. Nowadays, there is a plethora of different trolleys suitable for a certain type of operation or trolleys for universal use. Like two-wheel trolleys, three-wheel trolleys are among the simplest trolleys in terms of design. Depending on the type and characteristics of the material to be transported, they vary in their construction. The choice of trolleys is influenced by many factors, mostly technical, which are constantly being improved thanks to the competitive market environment. All companies strive to find the optimum solution, and since each has its own specific requirements, manufacturers strive for the widest possible range of products to offer their customers. The choice of trolleys from each manufacturer is so large that it satisfies almost every customer and this is where design comes in. The latter does not take the machine as the sum of its parts, but as a whole that tries to adapt as much as possible to the user's needs.

Design of the structure of the three-wheeled unit

For the design of the three-wheeled unit was purposefully used CAD system from Autocad called Inventor, mainly to show the simplicity of designs in modern CAD - systems. The design itself is designed to be as simple as possible with regard to assembly and assembly, but mainly also for maintenance and possible necessary component replacement. The design of the three-wheel unit consists of two basic types of components, standardized, commonly available on the market and also components that need to be manufactured. The production of these components means using bending and cutting, but also chip machining and of course welding. [5]

Determination of parameters for the design

- Outer dimensions to be less than 1650x900x1300mm
- Storage space for transporting boxes min. 600x400x200mm
- 750W electric motor drive
- Possibility of attaching an outboard trolley
- Use of rear wheels size 3.00 - 4 (260x85)
- Intelligent features and peripheral components for industrial use
- Maximum speed in the range of 12 - 15km/h

Frame design

The basic premise for the design of the frame (skeleton) was the time-tested shape of the most commonly used motorless tricycle on the market, while the design also incorporated a drive by means of an electric motor, from which the torque is transmitted to the rear axle and then to the wheels by means of a chain. The design of the skeleton was carried out in several linked versions, each of which entailed an improvement in the final characteristics of the proposed three-wheeled unit. The original, initial intention for the design of the carcass and its construction initially appeared to be a good choice of base material, a closed square section - yakel with an outer dimension of 40x40mm, wall thickness of 3mm, which was later replaced due to fewer welds and the possibility of simpler forming with 42mm diameter tube. A 22mm pipe is used for the seat.[5]

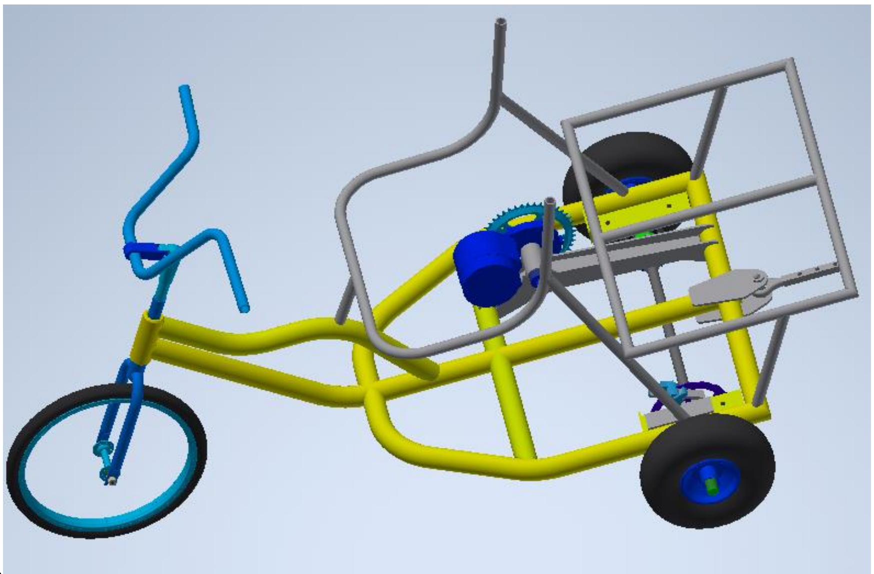

Fig.1 Positioning of the seat [5]

Engine positioning

To accommodate the engine, a bracket was modelled consisting of a tube in which the engine is housed, placed between two sections made of 5mm thick sheet metal, between which reinforcements were placed. From the positioning of the seat on the proposed carcass, it was found that the positioning of the engine and its mount was inappropriate Figure 2 (the engine would interfere considerably with the legs during the ride), the solution is to move the position of the engine towards the rear of the carcass.

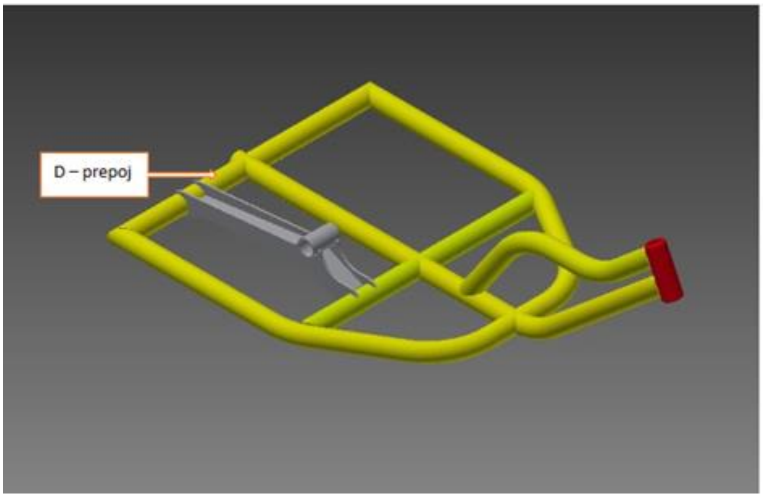

Fig.2 Position of the motor holder [5]

Bafang BBS-02 motor and C965 control unit

The motor with the supplied accessories figure 3 is placed in the bracket and transmits the torque to the rear motion gear via a 46 tooth gear. The motor has a maximum output of 750W, it is originally designed for sporting purposes to rebuild bicycles by placing it in the centre compound. A 48V lithium-ion battery is used as the power source, currently manufactured in two versions, namely 14Ah or 17.5Ah. The battery supplies power to the motor by means of a Bafang C965 control unit Figure 3. This unit can be used to set nine preset motor power stages, while it is also possible to change the power characteristics for individual stages by reprogramming them via software. Other functions of the control unit include speed display, distance travelled, automatic backlighting, temperature display, battery level (also the possibility of setting minimum and maximum battery voltage) and also the power/consumption of the motor is continuously displayed. The unit itself has minimal impact on battery discharge due to its low power consumption (10 to 30mA) [2].

Fig.3 Bafang BBS-02 and control unit [2]

Transmission gears

The advantage of chain drive rather than direct drive from the engine to the rear wheels is that there is a choice of the ratio between front and rear gearing. This ratio directly affects the maximum speed and the resulting tractive effort of the proposed tricycle. Since the motor is supplied with a 46 tooth gearbox, the gear ratio option and therefore the overall speed is only in the size of the rear sprocket of the derailleur - the pinion gear. The choice of this gearing was based on standardized parts used on e-bikes, and its approximate size was determined by calculation. To calculate the gear teeth of the gear-pinion and thus to determine the final maximum speed, it is necessary to know the engine speed, which is declared in the technical data sheet issued by the manufacturer, and the second necessary value is the diameter of the rear driven wheels. The technical data sheet of the Bafang BBS-02 engine is given in Table 1. and states the maximum speed at nm=135 min-1, which means 2.25 engine revolutions per second, i.e. also the speed of the 46z-converter. [5]

Tab. 2 Technologies as initiative to a change

Product Description	
Position	Mid Motor
Construction	Gear drive
Rated Voltage (DCV)	48
n0 (Rpm)	160
Rated Power (W)	750
nT (RPM)	135
Max Torque	160 N.m
Efficiency (%)	80%
Pedal sensor	Speed
Shaft Standart	JIS
Noise Grade (db)	55
Operation Temperature	-20 – 45 C
Reduction Ratio	1:21:9
IP	IP 65
Certifications	CE/EN 14764/ ROHS

The technical data sheet of the Bafang BBS-02 engine is in Table 4. and indicates the maximum speed at value nm=135 min-1, which means 2.25 engine revolutions per second, i.e. also the speed of the 46z-converter.

$$nm = 2{,}25s{-}1 \tag{1}$$

The rear wheel is 10" in diameter and this means that one revolution of the wheel when the trike is in motion will is equal to a distance travelled of 0.79m.

$$okol = 0{,}79m; \tag{2}$$

The design parameters for the three-wheeled unit specify a maximum speed of 12 to 15km/h. For the design we will use the average , i.e. 13,5 km/h and that is:

$$vmax = 3{,}75ms{-}1 \tag{3}$$

The required number of revolutions of the rear wheel for maximum speed is therefore calculated from the maximum speed and wheel circumference.

$$n_{kol} = \frac{v_{max}}{o_{kol}} = \frac{3{,}75}{0{,}79} = 4{,}68s^{-1} \tag{4}$$

The necessary transmission between the electric motor and the rear wheel is in this case:

$$i = \frac{n_{kol}}{n_m} = \frac{4,68}{2,25} = 2,08; \quad (5)$$

The number of teeth of the rear derailleur - pinion is calculated from the relation:

$$i = \frac{z_m}{z_{kol}} = \frac{n_{kol}}{n_m} \quad \Longrightarrow \quad z_{kol} = \frac{z_m}{i} = \frac{46}{2,08} = 22,11; \quad (6)$$

Standardized gearing is with the number of teeth 18, 20, 22, 24, 26. to the calculation 22 tooth gear - pinion Figure 4

Fig.4 Rear 22-tooth wheel [5]

The state of the electric smart trike before the design elements are implemented can be seen in the following Figure 5.

Fig.5 Steel frame of the electric tricycle

Testing tricycles

As part of testing the trike, its functionality and proposed design elements, we subjected the trike to a test ride on the campus of the Technical University in Košice figure 6 to test the drive, speed, functions of smart devices such as tablet, front camera and last but not least the fairing of the device itself. It was tested both on a flat surface and on uneven surfaces to verify its stability and the strength of the individual components that were installed on it. We also tested the various clacking noises that can be caused by poor attachment to the frame of the trike. The device showed good rideability, a very good degree of turning and stability itself.

Fig.6 Electric tricycle testing

Conclusion

The use of electric tricycles in industry is an innovative and efficient way to increase productivity, improve safety and reduce environmental impact. Electric tricycles offer many advantages over traditional vehicles and are an ideal solution for a variety of industries. In industry, electric tricycles can serve a variety of purposes such as cargo transport, supply, monitoring and maintenance. Their sturdy construction and load carrying capacity allow them to carry heavy loads and provide stability even on uneven terrain. They can be equipped with various accessories and adapted to the needs of a specific industry. Given the ever-increasing demands for sustainability and efficiency in industry, the use of electric tricycles is a promising and forward-looking option. Their use can help to reduce costs, increase productivity and create a more acceptable and environmentally friendly working environment. Ultimately, the use of electric tricycles in industry is a viable solution that benefits not only businesses but also the environment. Their cost-effectiveness, environmental sustainability and practical benefits make them an essential part of the modern industrial environment.

Acknowledgments:

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MILK-RUN 4.0 – SUPPLY SYSTEM IN CONDITIONS OF INTELLIGENT PRODUCTION

Martin KRAJČOVIČ - Patrik GRZNÁR - Martin GAŠO - Štefan MOZOL - Dávid KOMAČKA

Abstract: The milk-run system represents a time-proven and efficient method of supply in lean production conditions. Its principles were applied both in external (procurement of material from suppliers, distribution of products to customers) and in internal (supplying workplaces with components) logistics. The internal milk-run system is based on the supply of production workplaces in the form of mixed deliveries of small quantities of individual components, usually at regular time periods and along fixed circular routes. The implementation of Industry 4.0 in production plants also brings new requirements for the method and functioning of internal logistics. The answer to the challenges of intelligent production is the milk-run 4.0 system based on the use of new digital technologies and dynamic scheduling of supply routes. This article describes the basic characteristics of the milk-run 4.0 system and their comparison with classic lean supply systems.

Keywords: milk-run, intelligent production, internal logistics, dynamic supply routes

Introduction

The internal milk-run system represents a system of lean supply of workplaces with individual components necessary for production or assembly of products. It is often used mainly in production systems characterized by small series production with sufficient repeatability and thus also sufficiently stable requirements for supplying workplaces with components.

The milk-run system has proven itself as a highly efficient supply system, which, when properly designed and implemented, can ensure optimal utilization of logistics equipment and personnel, high predictability and reliability of deliveries, and smooth production with low inventories.

In-house milk-run system

The internal milk-run works on similar principles to the supplier milk-run from which it originally originated. The assigned vehicle sets out on a route from the incoming warehouse (or supermarket), visits individual workstations in the production system (e.g. on the production line) along the way, and then returns to the starting point. During visits to individual workplaces, he supplies individual production positions with material and at the same time can also collect finished products and empty containers along the route (Fig. 1).

Basic characteristics of the milk-run supply system [1]:

- driving means of transport along optimal circular routes,
- transportation according to a prearranged time schedule,
- precisely determined stops and points of delivery of individual components,
- transport of mixed batches (several types of components in smaller quantities),
- the use of tugger trains for the transport of components,
- application of the pull approach when supplying workplaces with material.

Over time, several variants of the milk-run supply system have been developed in practice, which differ in some management principles and the degree of automation of individual logistics activities. The main parameters that distinguish individual variants of supply systems include [2]:

- method of storing material inputs,
- handling units used,
- the principle of stock replenishment,
- type of supply route,
- assigning means of transport to routes,
- the principle of management of the supply system,
- degree and form of integration of the picking process into the supply route,
- degree and form of integration of the process of collection of empty containers into the supply route.

Theoretically, by combining different configurations of these parameters, it is possible to create a large number of possible milk-run supply system concepts. However, only a few basic concepts have emerged in industrial practice, which have some common features [2]:

- almost all concepts work with fixed circular routes,
- means of transport are always assigned to one route,
- the process of collecting empty containers is usually integrated into the milk-run route,
- in practice, systems working with small handling units prevail,
- most processes using small handling units work with a fixed schedule,
- in practice, a balance is usually maintained between the number of empty containers taken and the number of full containers delivered (1:1 exchange).

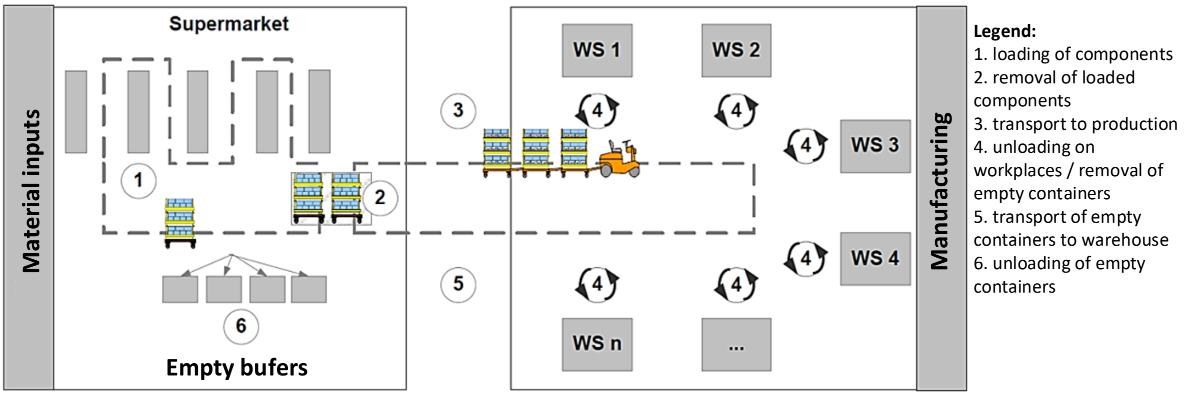

Fig. 1 An example of a milk-run supply system [2]

The application of lean supply systems results in a reduction in the number of logistics workers in the workshop, elimination of time spent searching for components by operators, reduction in the need for areas for component storage, reduction in component stocks at workplaces, increase in stock turnover, increase in transport safety and reduction in costs [3].

Industry 4.0 and internal logistics

Production and logistics systems are currently undergoing revolutionary changes. They acquire new properties and functionalities. Machines, robots and products are becoming intelligent, and advanced information and communication technologies are becoming the central nervous systems of future production. Production and logistics systems must above all be adaptable, able to adapt autonomously, actively and quickly to sudden and unexpected changes that arise in their surroundings and exceed the boundaries of the system's originally defined functions. Such a system must therefore have the ability to change not only its structure, but also its functions and capacities. Internal logistics must also respond to these changes, conditioned by the fourth industrial revolution and the effort to build intelligent factories (Smart Factories). Logistics systems must have completely new properties, such as: self-organization, reconfigurability, autonomy, self-optimization, self-replicability, or the ability to learn and work autonomously with the creation and use of knowledge [4].

In the conditions of Industry 4.0, certain limitations of the classic milk-run supply system, which result from its basic characteristics, begin to manifest themselves. For the collection of data on the needs of individual workplaces, various variants of pull systems are used, which, however, ensure the collection and processing of requests in batches and thus also with a certain delay. Together with fixed schedules and fixed routes, this reduces the overall flexibility and adaptability of the milk-run system to current and unexpected situations in production, which are key features of intelligent manufacturing and logistics [5].

Milk-run 4.0

In order for the milk-run supply system to be implemented in intelligent manufacturing plants, two basic conditions must be met:

- knowledge of the current status in the production and logistics system in real time,
- the ability to dynamically adjust the workplace supply mode to the current state and requirements.

The provision of the first condition is made possible by the application of progressive technologies of data collection and processing and tracking and localization of logistic means in real time. Automatic identification technologies, such as RFID (Radio Frequency Identification) allows us to monitor the stock status of individual components at individual workplaces and the development of their consumption. Systems for locating objects in real time (RTLS - Real Time Location Systems) provide information on the current location of individual logistics devices (transportation means, handling units), their movement in space, the current transport task they provide and the state of its development [6] .

All this data can be acquired in real time and form the database for the digital twin of the in-house logistics system. This creates prerequisites for knowledge of the current and real situation in the production and logistics system, location, condition and current utilization of individual logistics resources. At the same time, the digital twin helps to predict the development of the requirements of individual workplaces for individual types of components [7] .

This prediction, together with the knowledge of the current status and utilization of logistics resources in production, creates a database of input data for the very management of the milk-run supply process, the core of which is the generation of individual milk-run circuits and runs. Due to the high requirements for flexibility and adaptability, the actual scheduling of supply routes in the milk-run 4.0 concept must take place dynamically, which means:

- the start of individual runs at variable moments in time, adapted to the current needs of production,
- the design of dynamic circular routes, optimized for the current state of production requirements and capacity utilization of the logistics system.

Scheduling in milk-run 4.0 conditions therefore requires the implementation of the following steps:

1. Initialization of the scheduling process, which is conditioned by the current state or by predicting production requirements for individual components.
2. Evaluation of the current state and prediction of the time profile of the utilization of logistics capacities.
3. Synthesis of production needs and available logistics capacities.
4. Design of a dynamic circular route / circular routes to meet production needs.
5. Realization of workplace service according to the designed milk-run routes.

a) automated logistics system *b) navigation using augmented reality*

Fig. 2 Realization of supply in the milk-run 4.0 system

When designing optimal circular routes, the so-called VRPTW (Vehicle Routing Problem with Time Windows) task [8], i.e. the vehicle routing problem with time windows, which solves the problem of servicing a group of customers (workstations), within the framework of a common optimal circular route, while observing the delivery time of individual components to individual customers in exactly specified time intervals (time windows). In this case, the modification of the circuit route problem with consideration of time windows is necessary in order to ensure the delivery of components to individual workplaces at the right time, i.e. so that they are not delivered too far ahead of time and do not create excess stock at the workplace, but at the same time so that they are not delivered too late, which could causing inventory shortages at the workplace and ultimately, production disruptions. For the actual solution of VRPTW tasks, there are a number of heuristic and metaheuristic approaches that can be implemented in the digital twin model.

The output of the scheduling is digital routes [9], which are intended for the management of automated means of transport (Fig. 2a) or the navigation of transport operators (visual navigation using tablets or means of augmented reality, Fig. 2b).

Conclusion

The principles of lean production are still relevant today. In its activity, every company tries to eliminate waste in processes that do not add value to the product, but unnecessarily exploit company resources and lead to the consumption of excess time.
current businesses cannot only be "lean" but must also be sufficiently "agile" to be able to flexibly adapt to constantly changing conditions (customer requirements, changes in the company's internal and external environment). This also requires a change or modification of some approaches used in lean production. An example of such a change is the Milk-run 4.0 system, which represents the functional adaptation of lean supply to the conditions of Industry 4.0, while maintaining its basic advantages: high supply reliability, low inventories, optimal capacity utilization and low logistics costs.

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DIGITAL TRANSFORMATION IN PORT DEVELOPMENT: SUSTAINABILITY, INTEGRATION, AND INNOVATION

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Abstract: This article addresses the current challenges in the development of maritime ports in the context of digitalization. Traditional approaches are no longer sufficient for international competition, necessitating ports to focus on sustainability and digital transformation. The European Commission emphasizes the need for decarbonization of ports. Port of Valencia is showcased as a leader in digital transformation and sustainability. The article also introduces projects aimed at integrating ports with cities and improving environmental performance. The goal is to highlight the importance of connecting digital port and city platforms for smarter maritime ports.
Keywords: Sea Ports; Digitalization; Digital Transformation; Sustainability; Decarbonization.

Introduction

The traditional approach to the development of seaports involved infrastructure design and competition based on prices to attract cargo. However, this model is no longer sufficient to compete in the international port sector. Modern ports must focus on sustainable development and adding value to society [1]. Digitalization has become a key element of this evolution, requiring collaboration among various stakeholders, including ports, local authorities, and global supply chains [2]. The European Commission emphasizes the need to reduce carbon emissions and improve the environmental performance of ports, as reflected in the European Union's (EU) 20-20-20 goals and the Commission's communications (COM 2013(295) "Ports: Engines of Growth" and COM 2013(17) "Clean Energy for Transport"). The latest step is the Fit for 55 package, addressing infrastructure for alternative fuels and FuelEU Maritime regulations. The Port of Valencia stands out in the field of digitalization and sustainability compared to other ports. It is a leader in economic, social, institutional, and environmental aspects, as well as in digital transformation. The Port of Valencia is committed to digitalization, sustainability, and integration with the city. This article presents two projects aimed at integrating the port with the city and improving environmental performance through digitalization and innovation. These projects support the connection of digital smart port platforms with urban platforms (smart city ports).

Utilizing digitalization as a tool to achieve environmental sustainability - The Green C Ports Project

The Green C Ports Project [3] is co-financed by the European Union under the Connecting Europe Facility program with the aim of enhancing port connectivity, integrating them with cities, and ensuring environmental sustainability of port operations within the TEN-T, the Trans-European Transport Network. The project includes four case studies at the Port of Valencia: the first seeks to reduce road traffic congestion in the port area using predictive models for trucks; the other two studies address air quality and noise in the port through sensors and meteorological stations; the final study measures emissions in real-time within delivery chains. At the Port of Valencia, an extensive sensor network has been installed, comprising 7 air quality sensors, 2 environmental monitoring stations, 3 noise meters, 8 intelligent cameras for traffic monitoring, and infrared remote sensors for detecting emissions from ships anchored in the port. Additionally, some ships and vehicles are equipped with continuous emissions monitoring systems, helping to calculate the carbon footprint in the logistics chain from door to door. This entire sensor network is connected to the port's environmental platform, and for the development of this platform, the Osisoft PI System tool [4] was chosen, enabling the collection, analysis, delivery, and visualization of data from sensors.

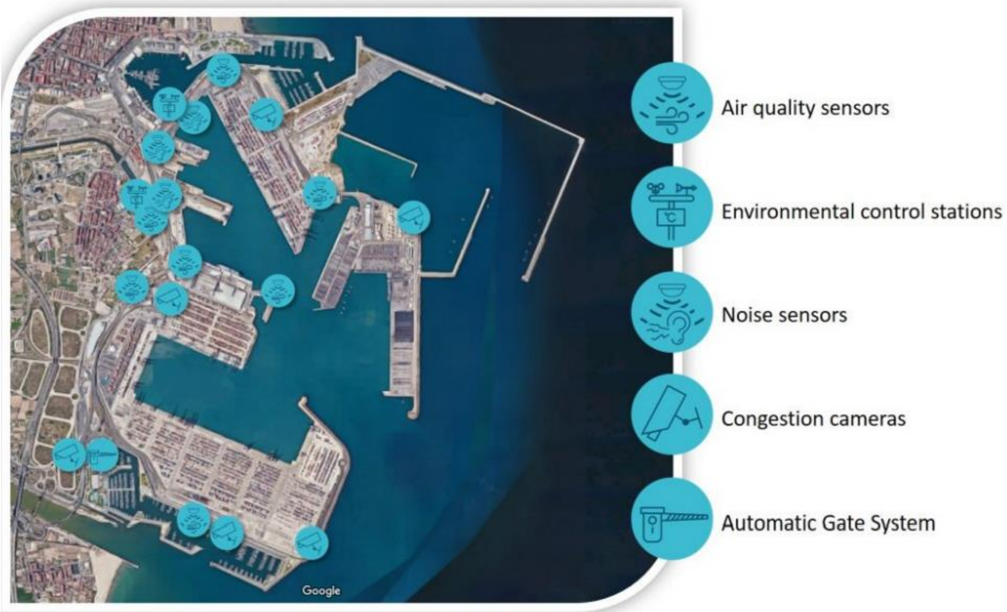

Fig. 1 The network of sensors installed as part of the Green C Ports project [5]

The following diagram illustrates the architecture of the solution used in the project to achieve the set objectives in the case studies. Using the PI tool, the environmental platform was configured to create digital replicas of all systems and devices in the sensor network, as well as various connections that enable the reception and storage of all data. These data serve to establish a history for artificial intelligence algorithm modeling, providing a real-time snapshot of the port's congestion, air quality, and noise levels in the short and medium term. Thanks to a set of control panels and web services implemented in the final layer, users can stay informed about various key environmental parameters related to congestion levels, air quality, noise, and emissions resulting from port activities. Through web services, this information is shared with other users outside the port, primarily with the city. For this purpose, this port platform will be integrated with various smart city platforms.

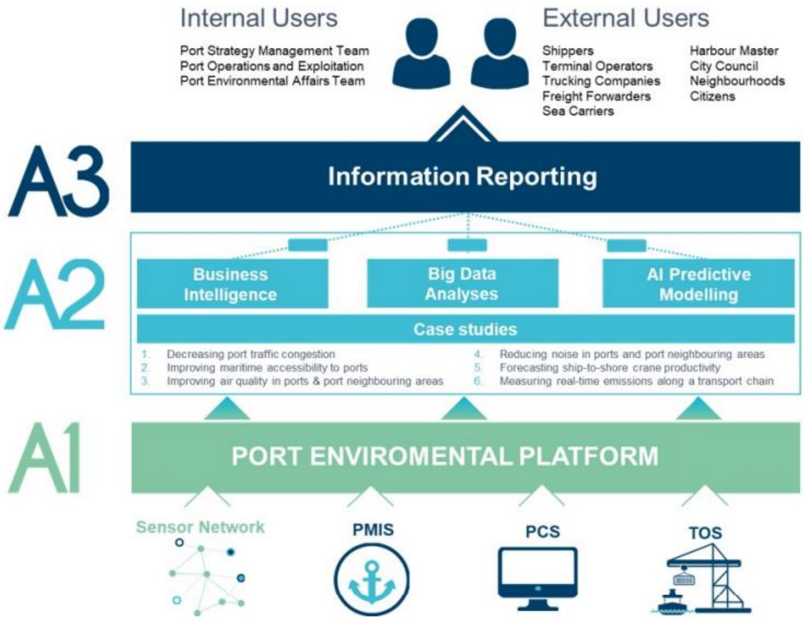

Fig. 2 The Green C Ports architecture implemented at the Port of Valencia [5]

This project contributes to reducing the negative impact of port operations on the city, regulates emissions from the port and vessels, optimizes cargo handling, and simplifies the arrival and departure of goods to and from the port.

Tracking passenger movement on cruise ships: The HERIT-DATA Project

The city of Valencia is an irresistible attraction for tourists: in 2019, it was visited by more than two million people before the outbreak of the COVID-19 pandemic. Similarly, interest among cruise ship passengers has also increased, with the number of passengers on these ships arriving at the Port of Valencia growing by more than 125% (a total of more than 435,000 in 2019).

Fig. 3 Cestujúci na výletných plavbách v prístave Valencia [5]

To improve the tracking and management of passenger flows on cruise ships in the city of Valencia, the Valenciaport Foundation is leading a pilot project as part of the HERIT-DATA project [6], which is funded by the Mediterranean Interreg program. The project consists of three main phases: data capture, data processing for passenger identification on cruise ships, and visualization of tourist flows in the city. In the first phase, a cruise management system was developed in collaboration with the Port Authority of Valencia. This platform allows cruise companies to efficiently manage reservations for future cruise ship stops through a web interface. Additionally, it enables travel operators to record excursions organized for passengers on each of the previously registered cruise journeys. This information is crucial for determining future passenger flows on cruise ships arriving in the city. To track the movement of travelers on cruise ships in real time, sensors for counting people were installed at various strategic locations in the city. These sensors utilize LoRa [7] and NB-IoT [8] technologies and function as WiFi routers to detect tourists' phones and assign a unique identifier, which, after encryption, is stored and transmitted to the processing platform.

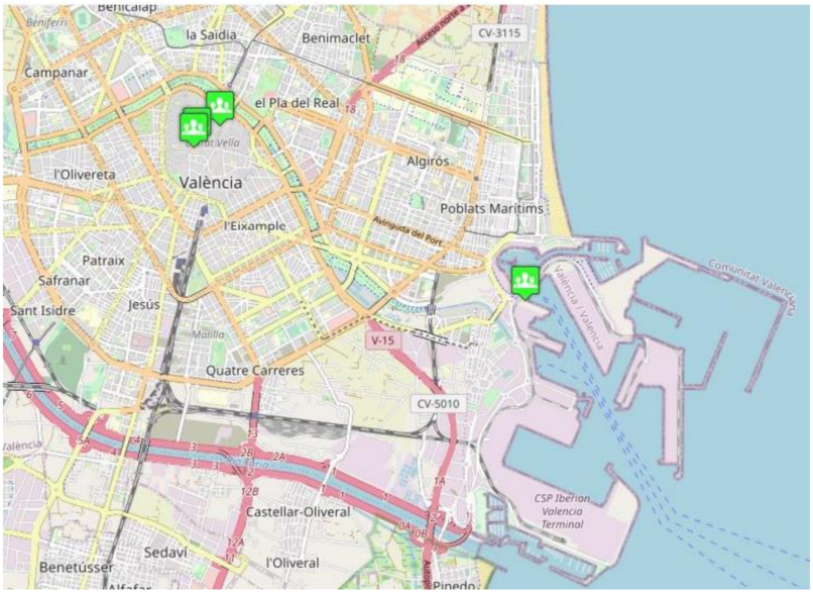

Fig. 4 Flow counting sensors installed in the city of Valencia [5].

In the second phase of development, a central platform was created within the Node-Red environment [9], which encompasses four main operations:

a) Regular measurement of the number of people at measuring points to estimate the flow.
b) Recording the activities of regular mobile users on excursion cruise terminals.
c) Temporary passenger registration on excursion cruises on the days of the arrival of excursion ships.
d) Detection of mobile passengers on sightseeing cruises at various locations in the city.

After completing the processes of measuring the flow (a) and detecting passengers on tourist trips in the city (d), this data is sent to the Snap4City platform, a multifunctional tool for the Internet of Things that enables tasks such as managing smart cities through real-time data storage, processing, and visualization [10]. The following image depicts the architecture of the solution from start to finish, which was implemented in the city of Valencia.

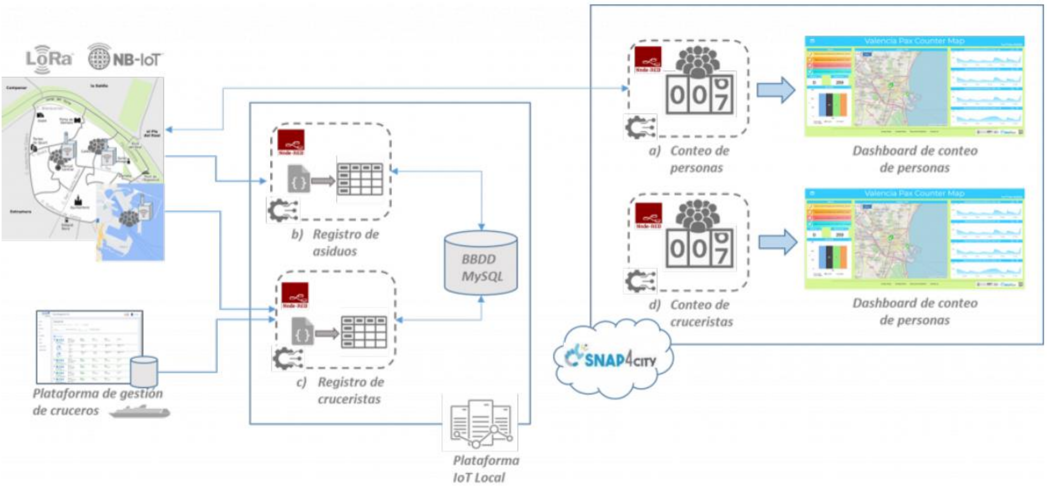

Fig. 5 The architecture of the pilot project HERIT-DATA in Valencia [5]

In this architecture, the registration process of regular users (b) relies on a sensor located at the port, which records mobile phone identifiers every 5 minutes and stores them in a MySQL database [11]. This process takes place on days without port arrivals and allows for distinguishing passengers on excursion cruises from local residents and other tourists when the cruise ship docks in Valencia. This process also consults the excursion cruise management platform's database to determine the expected arrival of the cruise ship. The registration of passengers on excursion cruises (c) involves temporarily storing passenger data when they disembark in a MySQL database for later detection by other sensors in the city through the passenger counting process (d). Finally, the people counting process (a) utilizes data from sensors in the city and the port to estimate the number of people at measurement points. In this way, the pilot initiative in Valencia brings the following benefits: real-time monitoring of the number of people at tourist locations in the city; understanding the flow of passengers on excursion cruises in the city to enhance their visitor experience; identifying the percentage of excursion cruise passengers compared to other visitors at measurement points; and understanding the role of excursion cruises in mass tourism. There are plans to expand the sensor network to additional locations in the city and measure other parameters related to the impact of mass tourism. This includes using sentiment analysis through social networks to assess the satisfaction of tourists and residents in the measured areas. Additionally, the use of artificial intelligence to predict possible overcrowding at tourist sites and support decision-making to mitigate its impact will be explored.

Conclusion

The Green C Ports project, funded by the European Union under the Connecting Europe Facility program, focuses on the digitalization and sustainability of ports. Within the project, four case studies are being conducted at the Port of Valencia, which relate to reducing road traffic congestion, improving air quality and reducing noise in the port, and real-time emission monitoring during cargo transportation. The result is an extensive network of environmental and meteorological sensors in the port, connected to an environmental platform. The Green C Ports project contributes to reducing the environmental impact of port operations on the city and enhances cargo handling. The city of Valencia is an attractive tourist destination, leading to an increase in the number of passengers on cruise ships. The HERIT-DATA project, funded by the Interreg Mediterranean program, monitors and manages the flow of tourists on cruise ships in the city. This project utilizes a sensor network to track the location of tourists in real-time and provides valuable information to enhance tourist experiences. Future work will involve expanding the sensor network and using artificial intelligence to predict overcrowding at tourist sites. These initiatives are examples of innovative use of digital tools to improve sustainability and efficiency in ports and tourism, combining digitization with environmental protection and providing essential data for decision-making in the city of Valencia.

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UTLIZATION OF NEW FORMS OF MARKETING

Peter MALEGA – Juraj KOVÁČ

Abstract: Marketing is a field that is constantly evolving. Existing conceptions are analysed and re-envisioned to reflect contemporary economic and social changes. Newer ideas develop as a result of technological advancements and marketing research. Marketing revolves around the wants and demands of customers. All marketing efforts are directed towards meeting the diverse needs of customers. So, it is essential to be aware of marketing because you can make an informed decision and select a type of marketing based on your requirements.
Keywords: marketing, marketing strategy, new forms of marketing, marketing communication

Introduction

Marketing is generally understood as a business method that enables a company to find a market for its products, to create a market and to systematically take care of this market. General marketing is based on the belief that the objectives of an enterprise can only be achieved if the enterprise has a perfect knowledge of the needs and wants of its customers, which it must know better and more thoroughly than its competitors. Effective marketing benefits not only the company but also the customer by helping them to find the product they need at the right time, in the right place and at an acceptable price

Distribution of marketing

If we want to think about the long-term prosperity of a company on the market, we must realize that success is linked to a marketing strategy, which each company must develop on its own.
Current marketing development trends can be summarized:

- New communication technologies, the transition of the company oriented to the needs of the whole market, through the orientation to the target groups, to the individual needs of customers - individualized marketing.
- The need for new perspectives on contractual, institutional and transactional relationships, such as networking of contractual partners, new strategic alliances, partnering with all external and internal stakeholders, customer involvement in the product development process, and resulting in networked relationship marketing.
- Marketing objectives will need to be operationalised (planned) for a very short period and for small groups of customers with an orientation to their changing lifestyles; specific marketing tools.
- Significant societal changes, the emergence of multicultural societies, changes in lifestyles, especially greater leisure opportunities, an ageing population, the erosion of national, regional and regional boundaries will result in the creation of new business and marketing structures and cultures.

Marketing can therefore be divided into:

1. Online marketing: Simply put, it is marketing activities that take place in a world of ones and zeros. Online marketing itself is already a very complex discipline. Therefore, we can still divide it into:

- Performance marketing: at its core are PPC ads (PayPerClick), a highly measurable and effective form of online advertising that allows for very precise targeting.
- Email marketing: you won't get many new customers by sending messages. It would be mass spamming. Nevertheless, e-mail marketing has its place in company communication. It is excellent for keeping in touch with existing customers. You can use it to tell them about new products, offer them interesting promotions or just wish them a happy birthday, for example.
- Affiliate marketing: not quite traditional, but a more interesting form of marketing. Affiliate marketing is based on partners who market your products for you. Of course, they won't do it for free. Therefore, expect to have to pay commissions. However, if the conditions are set well, it can be a very interesting sales channel.
- Social media marketing: this form of marketing is actually a combination of content and performance marketing. Social networks have become a virtual necessity for many companies and brands. In the discipline of reaching new customers and communicating with existing ones, it is still a great channel. But you have to know how to walk the walk. Properly set up, social media marketing combines engaging and valuable content with well-targeted advertising.
- Influencer marketing: an even more specific branch of social media marketing. It is based on working with people who have influence in the online environment, and especially on social networks. Influencer marketing can also achieve very interesting results when working with smart influencers.
- Search Engine Optimization: SEO (Search Sngine Optimization) , another notorious abbreviation that refers to the activity of optimizing a website and its content to make it as attractive as possible to web search engines and thus appear in top positions to users.

2. Content marketing: Content creation is a very important part of marketing. In particular, building your own brand and product awareness. This is because through content you can educate your customers, give them tips or simply entertain them. Content marketing doesn't just belong in digital. On the contrary, it can also be found in offline marketing.
3. Offline marketing: This primarily includes advertising space in traditional media and outside the Internet (Television, Radio, Newspapers, Magazines, Billboard campaigns, Conferences, Seminars, Lectures, Catalogues etc.)
4. Direct marketing: Although not very popular, this is also a form of marketing. It should be noted, however, that both legislators and local governments are gradually restricting various forms of direct marketing. This is because it can be unpleasant for customers. Moreover, these tactics have been popularly used by sellers with dishonest intentions. However, direct marketing can also be done in an ethical way. Direct marketing includes calls, emails, text messages, sending catalogues or even door-to-door sales.

Marketing strategy

Marketing strategy is a long-term concept of the company's activities in the field of marketing and its purpose is to allocate the company's resources thoughtfully and efficiently so that two basic objectives can be best met: customer satisfaction and achieving profit and advantage over competitors.

The marketing strategy (Fig. 1) determines what marketing tools the company should use, why, when, how and with what expected objective. It can take many definitions and forms, depending on the point of view and specific needs.

Fig. 1 Marketing strategy

New forms of marketing

Innovation is a modern word with which only a small number of companies can actually work. It is necessary to bring some creativity into your business and not to be afraid. There is no need to be afraid to experiment and also to look for newer approaches. Therefore, staying in the same place in today's environment doesn´t pay off, and without courage and a desire to change, business is unlikely to move to another, better level. We can sum up the new forms of marketing predicted by many global brands. The most important new forms of marketing are summarized in Tab. 1.

Tab. 1 Most important new forms of marketing

Rocket start of mobile advertising	On a daily basis, phone users turn to Google on the internet for information such as where to eat well, tips for trips, tips for books, recipes, etc. All you need today is easy to find in your phone. Mobile is an extended hand of contemporary man. The survey showed that Google uses more people on the mobile than on the computer, many times more. The development of mobile payments has also opened up new market opportunities and this affects the behavior of future customers.
Content marketing in the hands of the customer	Social networks such as Facebook, Instagram, or Twitter have pushed advertising to interactive communication between a brand and its fans. These social networks gave users a voice and a specific face. Companies are able to more closely monitor user behavior in real time and better tune their communication. Later, everything will be about a two-way conversation. Also product reviews, various blogs that present their opinion are also popular in this trend.

Video is a new king of content	Specifically, YouTube, Snap chat, Instagram videos, and video ads recently launched by Facebook are not new in this time. These video formats will continue to evolve to provide more space for so-called "visual storytelling". We' will see the videos in the most frequently seen places. Streaming is an extremely popular format because it saves a lot of time for the user and thus provides visual stimulation.
Using apps	Applications can simplify many activities today, they are much more intuitive, they are more flexible and much more fun. For example, applications can bring user to a purchase quickly and efficiently. A well-designed application can later provide a good advertisement to a brand. The quality application also spreads itself. Developers say that applications in the far future will even completely replace web pages.
Virtual reality as a 3D story of your brand	It sounds a little bit like sci-fi, but virtual reality has the power to invoke the "in time" experience. If our brain sees something, it tends to believe it. Oculus Rift and similar virtual programs represent a revolutionary medium that should serve as part of the marketing mix. As this virtual reality has the ability to display a live story, marketing professionals are given the media that gives the opportunity to introduce the product through this virtual world.
Even more personal data and metrics	Big data as well as statistics are an integral part of any one good marketer. They provide information about all customers, their purchasing habits. The boom of mobile online advertising and the growth of various applications allows the company to collect enormous amounts of specific data about their users and use it to influence them.
Social networks as a new websites	Every person nowadays takes social networks as a complement to marketing communication. However, this is a big mistake. The impact of social networks is enormous, and large known brands are beginning to think about this and realize steps to react on this phenomenon. Later, social networks will become a channel, and these brands can learn to work with benefits such as more personal contact with the target customer.
Wearable technology as a new kind of local marketing	Apple Watch, various fitness bracelets, as well as Google Glasses are the result of a new generation of technology devices that people wear right on their own body. However, for marketers, this means a source of irreplaceable amounts of data that will study our daily movement and behavior. So the advertisement will be targeted very narrowly.
The marketer's work will be even more challenging	Newer forms of media, respectively tools, have to perceive marketing as a discipline that is complex and such work in advertising will require an information base that every single marketer will have to create. There are many information, so the specialization on the single activity or tool will not be enough. On the other hand, the brand users themselves come with the help.
Brand value as a major measure of success	People are looking for true brands that have their story and with people that actually set up them. They want to know exactly who makes them, why this particular brand works, which exactly represents, what values it recognizes, respectively whether it brings added value to the world.

The role and effectiveness of marketing communication tools has changed very significantly. Companies are looking for new ways to reach the customer. This includes the trends in Tab. 2.

Tab. 2 Trends in marketing communication in the 21st century

Product placement	It is defined as the deliberate placement of a branded product, which is also paid, into an audio-visual work for promoting that product. Product placement is not only promoted in movies, it is also in television, respectively in computer games. Many researches has shown that product placement is targeted specifically, precisely and clearly to viewers from 15 to 25 years.
Guerilla marketing	Guerilla marketing is a marketing that combines unconventional thinking, originality and a link to unconventional communication channels. A large number of models and techniques to stimulate our thinking can be described as a space for creative thinking. Creativity is the basis of guerilla marketing, in which a large number of factors are combined.
Mobile marketing	Mobile marketing is one of the most dynamic and emerging marketing communication tools. Mobile marketing uses a variety of tools like advertising SMS and MMS, SMS competition, voting and pools, two-way SMS communication, advergaming, logos, etc.
Viral marketing	Specifically, viral marketing means creating an email message or some engaging marketing action that is "contagious" enough for a target customer to share with all their friends. Because the customers themselves spread this message, viral marketing can be cheap.
Word-of-Mouth	Word-of-Mouth (WOM) is a form of personal communication that serves to exchange product information between customers and their neighbors, friends, colleagues. It is the most effective communication tool. The WOM process is most often the result of consumer satisfaction or dissatisfaction with product or service quality, or customer care.
Websites	Websites are an essential part of the company's communications mix. They represent a platform that not only points to communication tools in the online environment, but more common to communication tools outside the Internet.
Online social media	Today, social networks are currently the fastest growing online segment in the world. Social networks are not only linking the world in the area of trade and money transfer, but also in the area of people-to-people relationships.
Neuro-marketing	In this modern time, neuromarketing is considered as a revolutionary super-trend. As a multi-disciplinary discipline, it combines and creates multi-disciplinary knowledge from various areas. General information about the brain are linked to the knowledge of psychology.
SEO marketing	The abbreviation SEO (Search Engine Optimization) is a setting for web pages that helps to optimize search engines such as Google.com, Yahoo.com, Ging.com. In this case, it is not only a problem from technical perspective, but it is also necessary to involve the creativity of the marketer, who is ideally also a copywriter. The whole SEO is mainly based on the correct choice of words that are used to build the site.
E-mailing	Sending emails to potential customers is one of the most effective ways to get a customer. It is also easy to maintain a customer relationship with emailing. However, the distribution of emails is still underestimated in many companies today

Conclusion

The changes that have been taking place in marketing and its different areas since the beginning of the 21st century can be described as a turning point. This is primarily due to the turbulent changes in the external environment of businesses. For example, the increase in the number of products and brands, the significant shortening of product life cycles, the fragmentation of markets into micro-segments, the increasing demands of customers and the difficulty of capturing their interest. Marketing is responding to these changes by changing its orientation and focus. The focus on maximising customer value and the need to bring the offer more effectively to the individual customer are becoming key. All of this is leading to gradual changes in corporate marketing communications.

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ANALYSIS OF THE EFFECTIVENESS OF THE LAYOUT SOLUTION USING SIMULATION SOFTWARE

Matúš MATISCSÁK – Richard DUDA – Martin MIKUŠIAK – Michal BALUCH

Abstract: The main purpose of the article in question is to establish a relationship between the creation of a layout solution and the conceptualization of an effective material flow in the environment of a newly emerging production hall. In the introductory part of the article, the development and optimization of processes in industrial and logistic environments is briefly considered. Subsequently, emphasis is placed on the significant impact that a properly designed layout solution and effective material flow has on the overall production efficiency. The practical part of the article is devoted in detail to the development of the layout solution and a detailed description of the material flow, specifically for a specific product. The developed design of the layout solution and material flow was subjected to verification through the simulation software called TX Plant Simulation, which offers statistical reports and outputs. From these reports, the production process takes 47.94% of the total time, while 52.06% of the time is allocated for transportation.
Keywords: Layout, Material flow, Simulation

Introduction

Process development and optimization in industrial and logistics environments is becoming an increasingly important factor in achieving competitive advantage and sustainable success for organizations in the 21st century. One of the key elements that has a major impact on the efficiency of these processes is the correct layout with material flow.

Correct layout with material flow is not a simple spatial arrangement of equipment and workplaces; it is a strategic element that affects various aspects of business operations. Its proper design and effective management allow the organization to achieve several key goals. This includes maximizing worker productivity, optimizing the use of space and resources, minimizing losses and inefficiencies, shortening delivery times, and increasing overall competitiveness [1].

Scientific research in the field of layout with material flow is increasingly focused on the development of methodologies and technologies that enable organizations to achieve these goals. The use of modern technological equipment, automation and data analysis plays a key role in the design and management of these layouts [2].

Spatial arrangement of the workplace

Layout, or the spatial arrangement of the workplace, has a significant impact on the efficiency of the entire company. It concerns the arrangement of individual production departments, workstations, tools, machines, and other necessary equipment with an emphasis on the movement of work [3]. The most important part of the spatial arrangement is the effective and purposeful placement of the production equipment so that the employee has the most efficient and best conditions for the performance of his work. Correct arrangement has an impact on the entire production flow, affects production costs, the costliest handling and transportation of material. Finding the optimal layout of the workplace is very complex and complicated, but it is very important for production efficiency [4].

Layout of the new production hall

The newly emerging production hall in the industrial zone in the Košice district Nad jazerom will have dimensions of approximately 90m x 60m. In contrast to the current production hall on the South Avenue, the entire production process will take place on one floor, where all products will be produced. The layout solution of the newly emerging production hall is shown in Fig. 1.

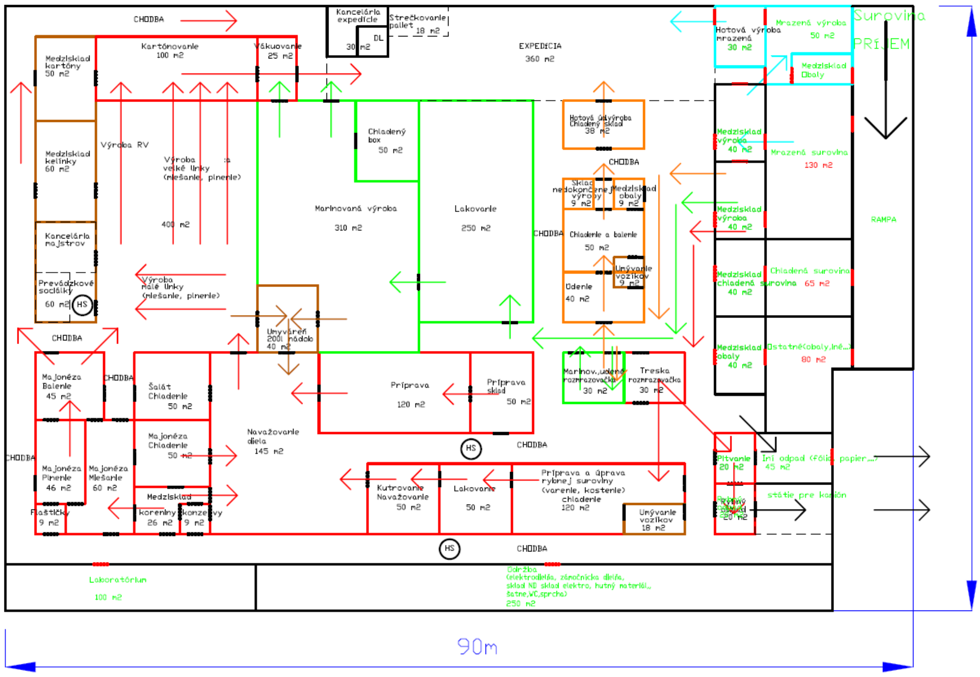


Fig. 6 Layout and material flow in the new production hall

The picture also shows the material flow of each production. Each color of the arrows represents a different material flow.

---> Frozen production   ---> Smoked production   ---> Production of fish products
---> Marinated production   ---> Garbage   ---> Containers

Material flow of a specific fish product

The material flow in the production of a specific fish product will start with the receipt of frozen fish raw material in the warehouse, while it will first have to be unpacked from the transport packaging. Subsequently, the necessary amount, which is consumed on a given day, will be moved to the intermediate warehouse. The first basic process will be thawing the fish raw material. After the necessary time has passed, the raw fish will be thawed and can be removed from the packaging. While it is being unpacked from the packaging, the quality of the thawed fish raw material will also be checked. The inspected raw material will then be transferred to the next production process, and that process will be cooking. After the specified time, the raw material will be cooked and ready for cooling. After cooking and cooling, the fish raw material will be marinated. After the marinating period, the fish raw material will be ground and then weighed. During this time, sterilized vegetables, and other necessary ingredients to produce a specific product will be prepared and weighed. The raw materials bound in this way will then be combined with mayonnaise. The mixture thus weighed and prepared to produce the product will be mixed in a new fully automatic line to produce fish products. This line will provide us with filling into jars, packaging, cartooning and then stacking cartons with the given product on the pallet, while conveyors will also be used. As the last process, the prepared pallet will be

wrapped with stretch film. Subsequently, the pallet will be ready for dispatch to the logistics-distribution warehouse.
In Fig. 2 and Fig. 3, the material flow of the production of a particular fish product is shown by red arrows. Black arrows show the material flow of waste generated during production. In Fig. 2 we can see the material flow of fish raw material preparation.

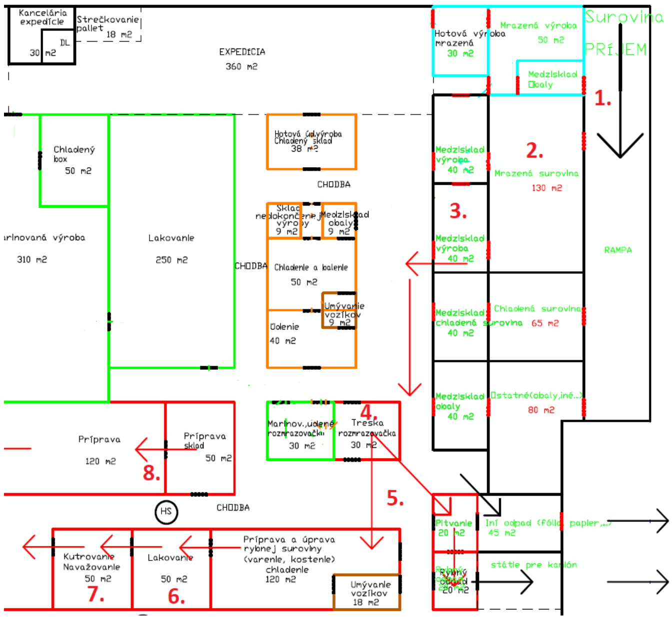


Fig. 7 Material flow of the production of a particular fish product – 1

Subsequently, in Fig. 3 we can see the material flow of weighing, production of a specific product, packaging, cartooning and as the last step is the shipment.

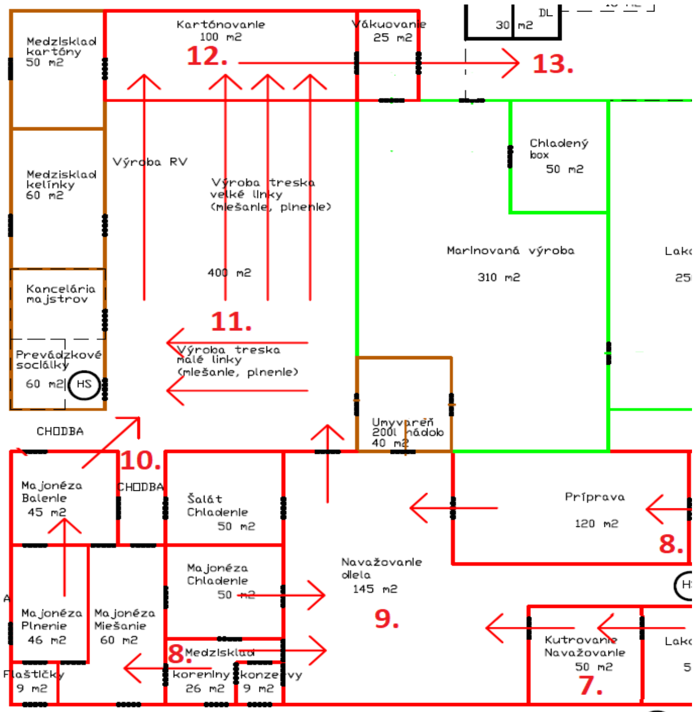
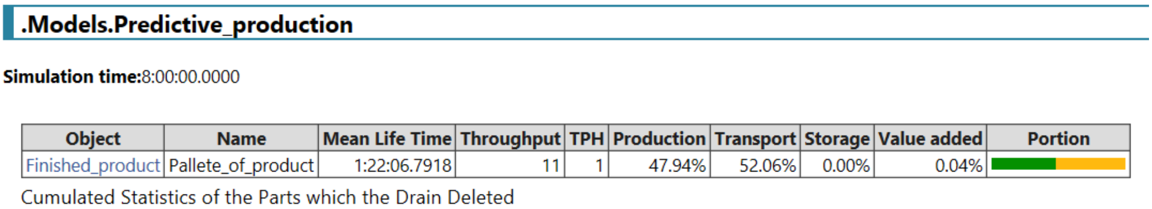


Fig. 8 Material flow of the production of a particular fish product – 2

The legend:
1. Intake of fish raw material,
2. Store of frozen raw materials,
3. Interim warehouse production,
4. Defrosting,
5. Preparation and processing of fish raw materials (dissection, cooking, cooling),
6. Painting,
7. Cutting and weighing,
8. Preparation of vegetables and ingredients,
9. Weighing,
10. Adding mayonnaise,
11. Production of cod or fish salads (mixing, filling),
12. Cartooning,
13. Shipping of packed pallets with the finished product.

Predictive simulation and evaluation of the result

The simulation of the production process of a specific fish product does not consider sometimes, since the entire production process takes about 3 days. A more accurate expression of the duration of the entire production process of the product is within 48 hours. Simulation time set to 8 hours.
In Figure 4, we can see the result of predictive production of a specific product in a newly emerging production facility.


.Models.Predictive_production

Simulation time:8:00:00.0000

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
Finished_product	Pallete_of_product	1:22:06.7918	11	1	47.94%	52.06%	0.00%	0.04%	

Cumulated Statistics of the Parts which the Drain Deleted

Fig. 9 Result of predictive product manufacturing

The results provided by the Tecnomatix Plant Simulation software in our report show that 11 pallets of a particular product can be produced and packaged during an 8-hour work shift. It is further noted that the production process accounts for 47.94% of the total time, while 52.06% of the time is devoted to transportation. These findings force us to conclude that the proposed layout is not optimal, and we will further investigate the simulations to achieve the most efficient layout.

Conclusion

The development and optimization of processes in industrial and logistics environments is constantly gaining importance as a key factor in achieving competitive advantage and sustainable success of organizations in the 21st century. A central and critical aspect in achieving the highest possible efficiency in newly emerging operations is a correctly conceived layout solution and an efficient material flow. These important points can be successfully achieved using industrial engineering methods.
Based on the statistical report provided by the simulation software Tecnomatix Plant Simulation, it is shown that the production process constitutes 47.94% of the total time, while

transportation occupies 52.06% of the process. Based on these results, it can be concluded that the proposed layout solution and material flow for a specific product are not optimal.
Our future research work will continue to improve layout and material flow. All these modifications will be systematically verified through simulation experiments, and we will continue to use industrial engineering methods in these modifications.

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SUPPLY CHAIN IN ACCORDANCE WITH THE FLEXIBLE MANAGEMENT MODEL

Dariusz MICHALSKI, Monika MICHALSKA, Marek KLIMENT

Abstract: We live in times of faster and faster changes on the market. We observe the dynamic development of trade and changes in customer preferences. Proper communication with the participants in the supply chain becomes very important. Flexible logistics is a way of organizing supply chains with the use of modern technologies so as to be able to immediately respond to the needs reported by customers as well as problems and unexpected changes. The concept of a flexible supply chain assumes obtaining better results thanks to an integrated approach to activities in the virtual sphere, market sensitivity and partnership cooperation. A flexible supply chain is customer oriented, meaning the ability to identify and meet demand. The article attempts to bring closer the topics related to: flexible management of the supply chain, its systems and the use of the cloud as well as blockchain technology.
Keywords: Supply Chain Management SCM, Agile, Flexible supply chain, Blickchain.

1. Introduction

Supply chain management (*SCM*) is the management of the flow of goods, data and financial resources related to products or services from the moment of purchasing raw materials to the delivery of the product to its destination.[10]

The supply chain is often identified with logistics, but logistics is only one of the components of the supply chain. Current digital supply chain management systems can be used by all parties that are involved in product or service development, order fulfilment and information tracking, including suppliers, manufacturers, wholesalers, as well as transportation and logistics entities. Operations that are performed along the supply chain include: ordering, product life cycle management, supply chain planning (including inventory planning and maintenance of company resources and production lines), logistics (including transport and fleet management), order management. Supply chain management can also include global trade activities, such as the management of global suppliers and international manufacturing processes.

The supply chain consists of three main steps:

- Procurement – refers to the method, place and time of obtaining and delivering raw materials for the production of goods.
- Production – that is, the transformation of raw materials into finished products.
- Distribution – all activities enabling the delivery of products to their destination. It is possible through a network of distributors, warehouses, stationary or online stores.[10]

Agile - a flexible approach to work, i.e. a way of thinking and working in line with the assumptions of the *Agile* Manifesto. In terms of design, a collective definition of agile software development methods based on an iterative-incremental model. It focuses on continuous product delivery with strong customer involvement in the process. The assumption is that the teams work agile, i.e. they quickly and flexibly adapt to changing customer requirements and external conditions. It is recommended for projects with unstable requirements and the lack of a clear, specific and unchanging vision of the final product. It allows starting operations without a set of detailed requirements and allows changing them without having to start work from scratch. Its main goal is to improve the quality of the product (understood as customer satisfaction and the degree of product refinement) so that it meets the real needs of the customer, not only the initial requirements.[1]

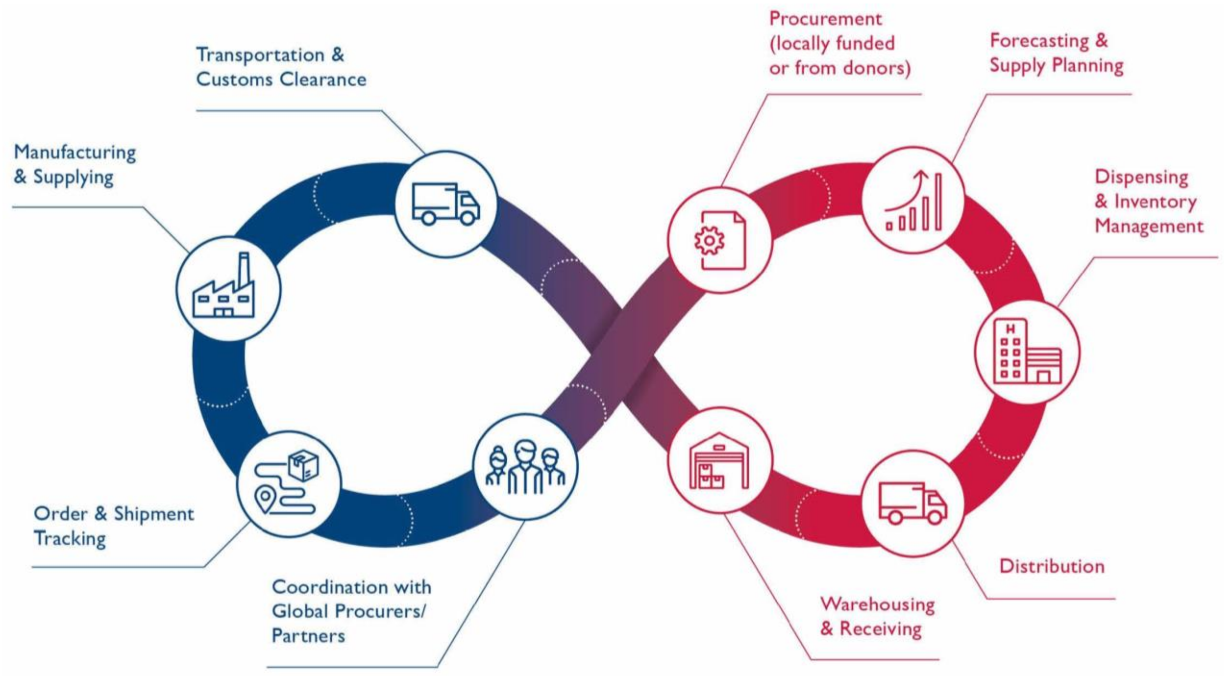

Fig.1. Flexible supply chain. [2]

The concepts of flexibility in production and programming became widespread at the turn of the 20th and 21st centuries in anticipating the challenges that the new millennium would bring. In the report “Strategy for manufacturing enterprises for the 21st century”, published in the early 1990s, a comparison was made between the agile manufacturing plants of the future and the common mass production plants characteristic of the 20th-century industry. This document puts forward an important thesis that in order to remain competitive in the global market, factories must implement a new approach to organizing processes and building relationships with the environment and customers. Some of the presented recommendations include: building close, partner networks of connections with suppliers, sellers and final recipients as well as within the enterprise; maximizing the importance of customer satisfaction in the overall organization of processes; identifying areas for improving the pace of performing tasks, improving efficiency and continuous development in all these areas and removing barriers that could stop it; developing an efficient production data exchange system.[5]

About 10 years after the issuance of the document described above, in 2001, a group of developers who met at a ski resort in the mountains of Utah prepared an agile software development manifesto. Within its framework, the four most important values of this method of work organization were named. They were prepared on the basis of juxtaposing the desired properties of the software development process in the Agile spirit with the functioning on the current principles. The result of their work was the following manifesto: “As a result of our work, we began to value more: People and interactions from processes and tools. Working software from detailed documentation. Cooperation with the client from contract negotiations. Responding to changes from the implementation of the assumed plan”.[10]

A lot of issues described as key in *Agile Manufacturing* and *Agile Development* are very important in the context of flexible supply chains.

2. Flexible supply chain management

In logistics, there was a need to obtain an answer to two phenomena: the increasing complication and complexity of tasks as well as the ever-growing emphasis on the flexibility of the company. In response to the above, the concept of the agile approach has emerged.

Flexible logistics is a way of organizing supply chains in such a way as to be able to immediately respond to problems, customer needs and unexpected changes using modern technologies. An agile approach to supply chain management is not limited only to the use of modern IT solutions. A very important feature of projects in this area is very high innovation and creativity. These projects are distinguished by high technological complexity. The main principle of all *agile* methods is iterative delivery of a working product. Another very important assumption for flexible methods is focusing on the flow of added value for the customer. In *agile* projects, the work breakdown structure is not defined, but the end product functionality breakdown structure, because it is the finished functionality that is the added value, not the work done. The concept of flexible supply chains allows expanding the capabilities and possibilities of operation to a level unattainable using any other method.

Agile logistics is a response to a situation in which the only constant is change, the life cycle of products is shortened, and the pressure on the possibility of individualising the product and the purchasing process is increasing. Customers expect to receive their order in the minimum time after placing it. In order to effectively increase the flexibility and pace of logistics processes while striving to minimize their cost, today a number of integrated solutions from the border of warehousing, forwarding, telematics and ICT are used.

An enterprise that is considered agile must be distinguished by:

- openness to changes and the ability to perceive them more as an opportunity and chance for development than as a potential threat;
- knowledge of changes taking place in the environment and flexibility in responding to these changes;
- systematic involvement of customers in the process of shaping the offer;
- awareness that the existing products, processes, solutions create limited and often short-term possibilities of staying on the market;
- possibility of access to resources enabling the implementation of innovative strategies;
- ability to take risks and bear responsibility for them;
- ability to search for and implement new concepts, ideas and technologies;
- possibility of obtaining the latest information on the state of research and development;
- correlation and cooperation with scientific, research and development, production and marketing units;
- possibility of permanent improvement of qualifications by employees;
- respect for natural resources and environmental protection.[6]

The above-mentioned features demonstrate that a flexible company is able to reconcile the advantages of mass production and continuous improvement programs with the speed and flexibility of responding to changes in the technology sector, trends and quantitative fluctuations. Thanks to the implementation of the agile strategy, the company has the ability to create new market trends. Moreover, it has the ability and knowledge to predict future customer expectations as well as awaken them in areas that can satisfy a particular company. A key issue in this strategy is the reservation of additional production capacity that may be needed to meet new customer needs quickly. This is very important because customers often have changing and diverse requirements, so when the need arises, the company must be able to quickly respond to market signals. [3]

The concept of a flexible supply chain assumes obtaining above-average capabilities through an integrated combination of virtuality, market sensitivity, process integration and partnership cooperation. A flexible supply chain is customer oriented, meaning the ability to identify and meet demand. In this particular case, the change consists in carrying out deliveries at the level of actual demand. To obtain such an effect, it is necessary to use innovative solutions such as the concept of effective customer service or other IT systems in order to obtain knowledge about the actual demand. This approach allows us to meet quickly customer requirements.

When analysing the concept of an agile supply chain, it is worth paying attention to the factors determining not only its formation, but also the need to increase its agility. The most common in this case are: *outsourcing*; supply chain globalization; increase in customer requirements; increase in the variety of the offer; shortening the life cycle of products [3].

The increase in the variety of the offer and the shortening of the product life cycle are perceived as potential threats, which suggests that enterprises must demonstrate more and more agility in order to cope with the expectations of the market environment. Globalization and outsourcing, for the needs related to increasing the agility of the supply chain, affect by extending the flow paths and increasing the number of partners, which significantly complicates the process itself and the implementation of tasks. The increase in customer requirements is also a factor most often perceived as positive, which in itself generates the need for greater agility and efficiency of operations. Flexible supply chains are based on the strict harmonization of organizational structures, IT systems, logistics processes and, in particular, human minds. Achieving agility requires actively shaping the potential of the supply chain in a way that gives it a strong competitive position in markets with shorter product lifecycles, increasing offer diversity and decreasing demand predictability.

3. Industry 4.0 and flexible supply chain management

The current completely new applications of modern technologies in the manufacturing industry are referred to as the fourth industrial revolution – the so-called Industry 4.0. In this latest image of industrialization, new technologies (such as artificial intelligence (AI), machine learning, Internet of things, automation and sensors) are changing the way new products are manufactured, maintained and distributed, and new services developed and delivered. It can be said that the basis of the Industry 4.0 concept is the supply chain. [9]

In this concept, the way companies apply these technologies to the supply chain is fundamentally different from the way they used them in the past. For example, in the past, an enterprise would wait for a computer to crash to fix it. However, the introduction of smart technologies has changed the way things are done. Now it is possible to predict the occurrence of such a failure and take appropriate preventive measures in order not to endanger the continuity of the supply chain. Supply chain management is therefore already about using the right technologies to improve the operation of the supply chain and the entire enterprise.

Supply chain management in the Industry 4.0 concept also has a significant advantage over traditional supply chain management, as it enables tailored planning and execution of tasks with significant cost savings. For example, companies operating under a “plan-to-produce” model, where production is as closely related to customer demand as possible, need to make accurate forecasts. This requires numerous measures to ensure that the production meets the demand reported by the market, but does not exceed it, and that expensive stocks are not released. Intelligent supply chain management solutions can therefore help meet both customer requirements and financial goals. [9]

Smart solutions for flexible supply chain management also have other advantages. Once implemented, some supply chain employees may be redirected to other, more productive tasks. These solutions can also automate routine tasks and improve the operation of the entire supply chain.

4. Systems for flexible supply chain management and the cloud

The definition of the cloud may seem confusing, but it is essentially a global network of servers, each with a different function. The cloud is not something tangible. It is a vast network of remote servers located all over the world. The servers are connected and function as one ecosystem. They perform a variety of functions: they store and manage data, run applications, and provide content or services such as video streaming, web mail, office software, and social networks. Instead of having data and files on one local or personal computer, it is possible to access them from any Internet-connected device – the information will be available anytime, anywhere.

Businesses can deploy cloud resources in four ways – using four types of clouds. The first type of public cloud that makes resources and services available to the public over the Internet. There is also a private cloud that is not shared and offers services over a private internal network (usually hosted in a given company). Another type is a hybrid cloud that provides services in both public and private clouds – depending on the purpose. The last type is a community cloud that only shares resources between organizations such as government institutions.

Cloud solutions are inherently designed to make better use of technologies that are increasingly used in the context of Industry 4.0. Enabling these technologies to operate on top of legacy applications is both complex and costly.

Another significant benefit of integrating the cloud with a flexible supply chain management system is that individual functions of the cloud system can be implemented based on specific business needs, without the need for a full-scale migration. A lot of enterprises have the short-term need to rationalize their transition to the cloud. The best systems help get the maximum benefit from the resources and make it possible to transfer these resources to the cloud to meet the current and future supply chain management needs.

5. Blockchain technology

Blockchain, or a chain of blocks, is a technology that stores and transmits information about transactions concluded on the Internet. This information is arranged in the form of consecutive data blocks. One block contains information about a certain number of transactions, then, after it is saturated, another block of data is created, followed by the next and the next, creating a kind of chain. Information about various types of transactions, e.g. trading, buying or selling currencies, including cryptocurrencies, can be sent there.[4]

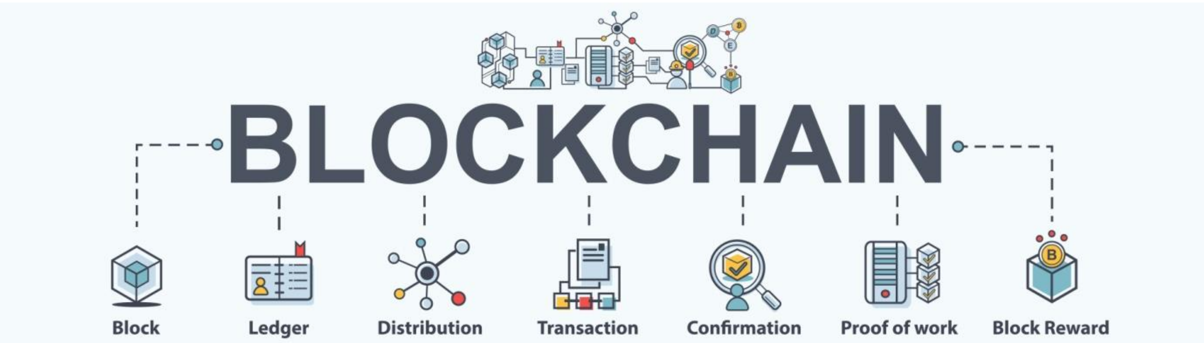

Fig.2. Blockchain. [8]

A company needs to be aware of what is happening in every aspect of its supply chain at all times. An appropriate system of flexible supply chain management should use *blockchain* technology and easily provide the necessary visibility and access to information within individual processes. This allows specific activities to be identified, to ensure that those activities are not denied, and to increase the degree of trust throughout the supply chain. [4]

This type of system can bring particular benefits to enterprises, e.g. in the food industry. For example, it enables companies to effectively manage a highly complex supply chain to provide greater insight, better forecasting, increase profitability, and strengthen trust-based customer relationships.

Nowadays, the best supply chain management systems are end-to-end product packages that help enterprises optimize and manage their supply chains as part of one complete ecosystem. These systems are fully integrated in the cloud, thus providing complete visibility of the entire supply chain and can be scaled up or down in response to the market situation. A modern, demand-driven supply chain makes it easier to cope with the challenges of increasing customer expectations, shorter product lifecycles and fluctuating demand.

6. Conclusion

The above article does not exhaust the issue of flexible supply chains. It is a complex and multi-layered issue, conditioned by many factors. Flexible logistics is a way of organizing supply chains in such a way as to be able to immediately respond to problems, customer needs and unexpected changes using modern technologies. In order to continuously develop the company, we are now forced to constantly evolve and improve our methods of managing the company and, among other things, the supply chain. Currently, it is very important to implement new technologies in our company, properly qualified and creative staff combined with modern technologies will ensure that we will be able to remain competitive on the market. The most important effect of introducing modern information technologies is the transparency of the entire supply chain. They extend the scope of management and enable managers to make operational decisions based on information received from a variety of areas where previously information was lacking. They become a means of supervising and controlling operations regardless of geographic location. The most essential aspects of the supply chain of the future will be responsiveness and level of customer service – these factors will be analysed and managed within a network model, not a linear one. Each node of the network must be both flexibly adapted to the customer's needs and capable of handling areas such as procurement, trade policy, shipping methods, etc. Advanced technology will increasingly be used both to improve transparency and visibility across the entire network and to support further connectivity and use of SCM functions. The entire scheduling function of SCM will become more intelligent to take into account the requirements of consumers. Adaptability will be mandatory.

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PROJECT OF INTRODUCING RTLS SYSTEM IN A MANUFACTURING COMPANY

Marek MIZERÁK – Peter TREBUŇA –Daniel DĘBOWSKI

Abstract: This article focuses on the design and implementation of the RTLS (Real-Time Location System) in a manufacturing company. In today's era of automation and constant search for optimization of manufacturing processes, RTLS emerges as a key tool for accurately tracking assets and resources in real-time. The primary objective of the project was to enhance manufacturing efficiency, minimize time losses, and optimize logistical processes within the company.
The article introduces a detailed proposal for the introduction of RTLS, including the selection of technology, sensor placement, and integration with the company's current information systems. The implementation encompassed the design of network topology, sensor placement, and calibration to maximize coverage and localization accuracy. Similarly, the compatibility with existing IT solutions in the company was thoroughly analyzed, ensuring a smooth integration of RTLS into current operational processes.

Keywords: RTLS, protection, implementation, project

Introduction

If we want to point to something, we need to know the correct location. A manufacturing business can implement processes to ensure that certain items are in a predetermined location and thereby increase sales. On the other hand, the company can also ensure the implementation of processes that will enable the employee to find material or tools in a significantly shorter time using localization technology. This case also focuses on security. Under this idea, it is possible to understand the possible finding of an injured person in large production enterprises and thereby increase the percentage of survival of a worker in a dangerous situation. Currently, the use of localization technologies in industrial practice is becoming more and more important. With the growing number of devices and objects in industrial complexes, the need for effective monitoring of their location and movement also grows. One of the ways to ensure accurate real-time positioning is the use of RTLS (Real-Time Locating System) technologies.

These technologies make it possible to effectively monitor and control the movement and position of various objects and equipment in an industrial environment. The aim of this bachelor's thesis is to explore the possibilities of using RTLS technologies in industrial practice, as well as to analyze their use and benefits. If we want to point to something, we need to know the correct location. A manufacturing business can implement processes to ensure that certain items are in a predetermined location and thereby increase sales.

On the other hand, the company can also ensure the implementation of processes that will enable the employee to find material or tools in a significantly shorter time using localization technology. This case also focuses on security. Under this idea, it is possible to understand the possible finding of an injured person in large production enterprises and thereby increase the percentage of survival of a worker in a dangerous situation. Currently, the use of localization technologies in industrial practice is becoming more and more important. With the growing number of devices and objects in industrial complexes, the need for effective monitoring of their location and movement also grows.

RTLS system

The Real Time Locating System (RTLS) is based on UWB technology, consisting of hardware and software that allows tracking the flow of material and personnel in a room.
Unlike other indoor tracking and positioning technologies, Sewio RTLS (Fig.2) uses dedicated interference-free UWB technology that is fully certified to ensure reliable and scalable performance even in the most demanding environments.
The high accuracy of the Sewio RTLS system provides an unrivaled flexible infrastructure for many existing and future business use cases.
Short deployment time Quickly create Industry 4.0-ready projects within budget and with less maintenance to gain broad support from all stakeholders.

Fig. 1 RTLS assembly

Proposal for deploying the RTLS system in the company

To calculate the technical security, it is necessary to measure the dimensions of the production hall and, based on these dimensions and the general rules of signal coverage, determine the necessary number of tags and anchors.
The subject of the RTLS system implementation was a production hall in which workers and material handling equipment are located. The company also uses forklift trucks. Therefore, when calculating the cost of the system, we need to calculate the cost of the tags that will be attached to these carts.

Fig. 2 View of the production hall

After analyzing the space, we measured the length and width of the room. The width is 13 m and the length is 27.5 m. After obtaining the dimensions, it was decided to choose two types of anchors that will be placed on the supporting columns of this hall. The anchors selected were eight Vista DirectFive anchors and two Vista Omni anchors. The layout of hall No. 2 and the location of the system can be seen in Figure 3.

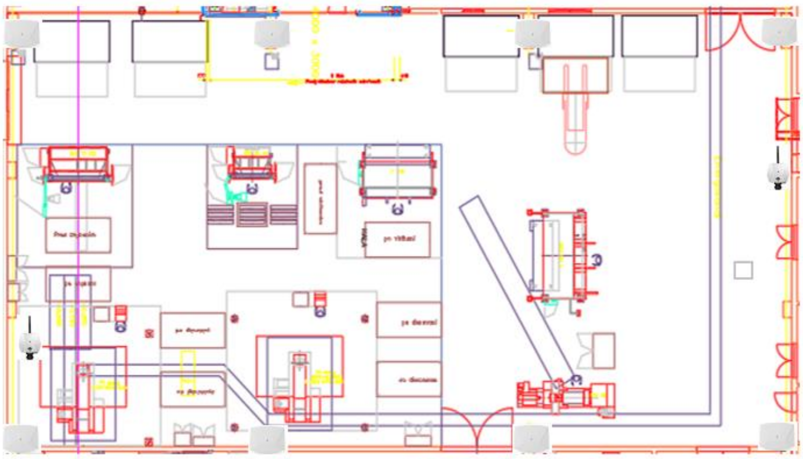

Fig. 3 Layout of the investigated area for the layout design of RTLS technology

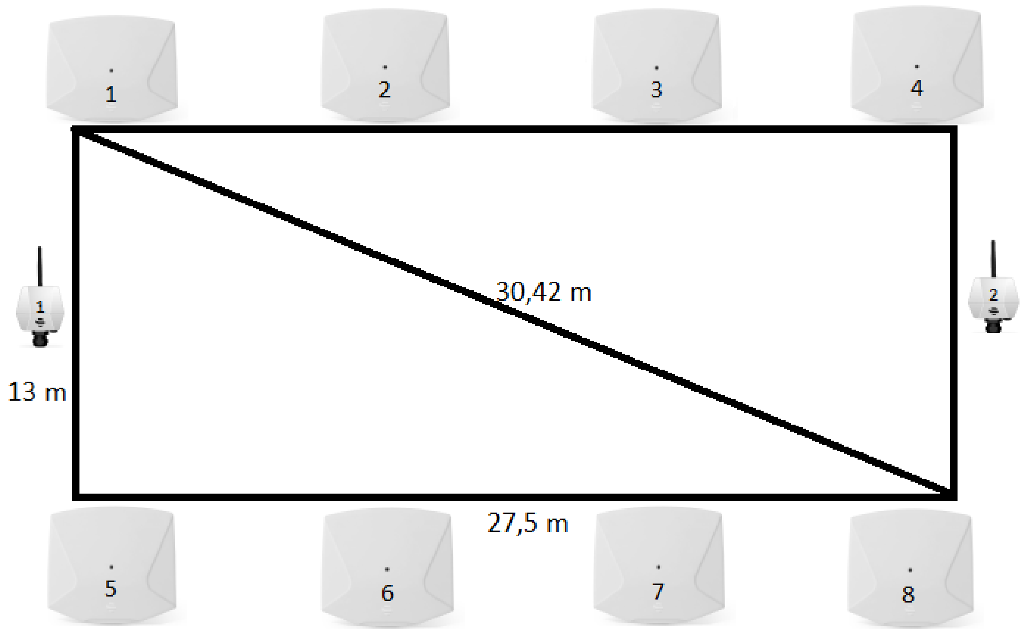

Fig. 4 Proposal for the distribution of two types of anchors in the examined area of hall no. 2

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Conclusion

One of the main advantages of the RTLS system is the improvement of work efficiency and productivity. This system allows you to monitor the exact location of products, equipment and workers, which reduces the time needed to search for missing equipment or product and reduces the time spent moving from one location to another. This can lead to increased work efficiency and reduced costs. A limitation may be the need to ensure privacy and data protection, as the RTLS system records the location of workers and equipment. In any case, the implementation of an RTLS system in a medium-sized enterprise should be considered based on the specific needs and goals of the enterprise. Should a business decide to implement an RTLS system, it can bring a number of benefits, but it requires careful planning, implementation and maintenance of the system.

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APPLICATION OF GENERATIVE PRETRAINED TRANSFORMER (GPT) MODELS IN INDUSTRY AND MANUFACTURING

Lucia MOZOLOVÁ - Štefan MOZOL - Patrik GRZNÁR - Martin KRAJČOVIČ - Milan GREGOR

Abstract: This paper provides insight into the application of generative pretrained transformer (GPT) models , such as GPT-4 developed by OpenAI , in the fields of industry and manufacturing. The paper discusses the capabilities of these models, such as natural language understanding and generation, and their role in service automation and personalization. The work presents concrete examples of how GPT models help to automate production processes, support the development of new types of software and services, and improve work with artificial intelligence in areas such as robotics and machine control. The article also deals with possible challenges and ethical issues associated with the use of these models. It also includes a discussion of the future development and potential of these technologies.
Keywords: generative pretrained transformer, agents, information demand, Excel, programming

Introduction

The first GPT model was released in June 2018, and since then OpenAI has gradually released more powerful models, including GPT-2, GPT-3, and the latest GPT-4 model. These models are general language models that have been trained to understand, generate and respond to natural language through deep learning and a massive training set containing millions of web pages. They are used in a wide range of applications, from content creation to conversational assistants. Generative pre-trained transformers (GPTs) like GPT-4, created by OpenAI , are one of the latest advances in artificial intelligence and machine learning. These models use powerful natural language generation algorithms, allowing text to be automatically generated based on information or instructions provided. They can be trained on a number of different tasks, allowing them to be used in a variety of fields, including education, manufacturing, and software development [1]. One important aspect of GPT models is their ability to understand the context given to them and generate accurate and relevant responses based on it. This can have a major impact on the way we interact with technology and bring new possibilities for automation and personalization of services. From the point of view of creating program codes, it can significantly reduce the demands on the user [2]. GPT models also have great potential in manufacturing and industry. Thanks to their ability to understand natural language and generate detailed and precise instructions, they can be used to automate production processes and make work more efficient in industry. In addition, models such as GPT-4 can be used to develop new types of software and services, which can bring new opportunities for technology innovation [3]. However, GPT-4, like its predecessors, is not without its challenges. Their use requires a large amount of computing resources, and their results, although often accurate and relevant, are not always perfect. There are also questions regarding the ethics and safety of using such models, especially regarding their ability to generate content that may be misleading or inaccurate [4]. The aim of the following text is to provide an overview of this new field of artificial intelligence, as well as to point out the potential that these technologies offer from the point of view of industry, using concrete examples of real involvement.

GPT in manufacturing

GPT models can also bring significant benefits to industry and manufacturing, especially in the context of industrial automation and robotics. Thanks to their ability to interpret natural language and transform it into specific actions, these models can help automate various manufacturing processes, leading to more efficient production and lower costs. One example is Groundlight, which has developed a platform based on the GPT model that allows programmers, regardless of their coding experience, to understand images programmatically using simple English instructions and a few lines of code [5]. This platform can be integrated into various applications such as industrial automation, process monitoring, retail analytics and robotics. An example can be the task when it is necessary to identify "Is the cart blocking the aisle?" based on this query, the answer is then implemented using the recognition of current records, see fig. 1. This technology is already implemented in Auster Manufacturing in Washington State.

fig. 1 Visualization of the process of identifying a response to a request for information [5]

Another example that outlines the future use of GPT is the application in robotics shown by the Microsoft study [6]. Robotics is one of the fascinating areas where ChatGPT can be used to translate natural language commands into executable code to control robots. The advantage of adopting ChatGPT for robotic applications is that they can start with a modest amount of sample data to adjust the model for specific applications and use its language recognition and interaction capabilities as an interface, see Fig. 2. Although the potential of ChatGPT for robotic applications is gaining attention, there is currently no proven approach for practical use.

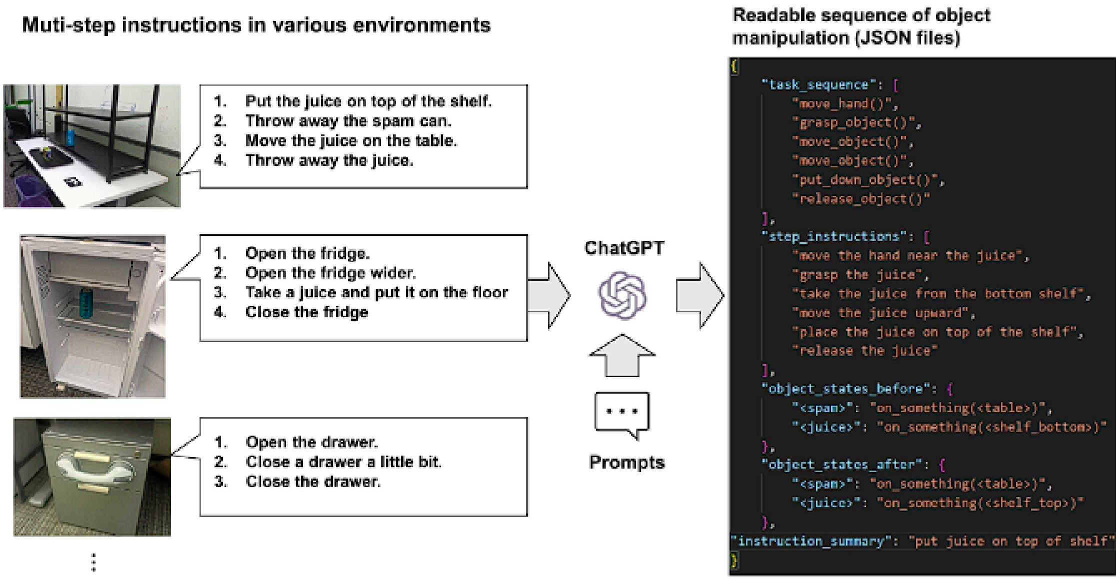

fig. 2 Visualization of the process of identifying a response to a request for information [6]

With the right design, GPT can also have another effect in the field and in the context of controlling machines with the help of commands in the code [7]. It is common that sometimes there is an error in the code that a trained programmer has to look for and often has to look for it directly on the spot while the machine can be turned off. A solution in the future could be a self-correcting "tool for artificial intelligence that corrects errors in the code. When a user runs their Python program and it crashes, the Wolverine -created tool teams up with the GPT-4 AI to fix the program and explain what went wrong. Wolverine's code is available on GitHub , and the developer says the technique could be used in other programming languages.

GPT Agents

AI "agents" capable of multi-tasking are another area where GPT models prove advantageous in a manufacturing context. These agents are essentially self-contained systems that use modern generative AI models to automate tasks. Most agents use OpenAI's ChatGPT and GPT-4 as a base, but several home agents also include generative AI models for images and voice to create surprising, if sometimes creepy, effects. These agents use the power of GPT models to automate various processes. For example, if you wanted an AI agent to create a plan to upgrade your computer on a limited budget, you could assign it tasks like "find and compare the latest graphics cards based on price under $500" and then the same for CPU, RAM and others. However, these benefits that GPT brings to manufacturing come with their own challenges. While these models have the ability to automate and streamline many processes, they also bring the potential for error. Developers must be vigilant to monitor AI output and possibly correct any errors that may arise. Despite these challenges, GPT models are a huge asset to manufacturing and industry, and their use in these areas will continue to grow in the coming years [8][9].

GPT in Microsoft Excel

Microsoft Excel has long been a basic tool for companies and individuals. It is a universal program that allows users to organize and analyze data in many ways. However, as the amount of data that companies and individuals work with grows, so does the need for more efficient methods of processing and analysis. This is where artificial intelligence (AI) comes in, and specifically Chat GPT. According to [10], one of the most powerful use cases of Chat GPT in Excel is the ability to generate natural language queries. Traditional Excel queries can be complex and require a deep understanding of the program's functions and syntax. But with Chat GPT, users can easily ask a question in plain language and get an answer in the same language. Another use case for Chat GPT in Excel is cleaning and formatting data. Data can exist in many different formats and may require cleaning and formatting before it can be analyzed. This can be a time-consuming process, especially with large data sets. With Chat GPT, users can simply input data and ask it to clean and format it for them. Of course, this does not happen in Excel itself, but in the GPT tool. Predictive analytics is the use of statistical algorithms and machine learning techniques to analyze historical data and predict future events. This can be a complex process that requires a deep understanding of statistical methods and programming languages. But with Chat GPT, users can simply input data and ask it to make predictions for them. Data quality is an important aspect of data analysis, but it can be difficult to ensure that the data is clean and accurate. With Chat GPT, users can perform quality checks on their data by entering data and asking Chat GPT to identify any errors or inconsistencies. One of the most important features of GPT is the possibility to create codes for VBA that allow automating most tasks without a person having extensive knowledge of programming [11].

Results and conclusion

As the analysis shows, GPT models such as GPT-4 can have a significant impact not only on the manufacturing sector, but also on everyday tools such as Microsoft Excel. In the context of manufacturing, GPT models show promising potential for automation and robotics. From the point of view of a specific application in Excel, GPT brings new possibilities and improves the user experience. One of the key benefits of GPT in Excel is the ability to formulate and answer queries in natural language, which facilitates interaction with the program for users without deep knowledge of Excel's functionality and syntax. Furthermore, GPT can greatly help with cleaning and formatting data, which is often a time-consuming and complicated process. GPT can also help with predictive analytics and data quality control, which are critical aspects of working with data in an enterprise environment. Finally, one of the most advanced capabilities of GPT in Excel is code generation for VBA, which makes it possible to automate most tasks without requiring the user to have extensive programming knowledge. This is an example of how GPT models open up new possibilities and simplify processes, which is in line with their potential in the field of manufacturing process automation and robotics, which we discussed earlier. Although GPT models offer many advantages, it is important to remember that there are still challenges and issues that need to be addressed. These include demands on computing resources, possible errors in generating responses, and ethical and safety issues regarding their use. These issues require further research and discussion. However, given the great potential of GPT models in manufacturing and in common tools such as Excel, their use is expected to only increase in the future.

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MODELING OF TRANSPORT SYSTEMS IN THE MINING INDUSTRY

Marek ONDOV – Ján PETROVSKÝ – Dávid KRASNIČI – Michaela BUGNOVÁ

Abstract: The transportation of raw materials in the mining industry is an integral part of the rock extraction process. The efficiency of transport systems is a logistical problem. Modelling and simulation are widespread procedures for assessing complex transport systems. The modelling procedure should also be efficient. Therefore, following the information gathering sequence, model shot, and specific on-site measurement is crucial. Models of mining transport systems often have the same core of loading and unloading processes, so it is worth considering the use of ready-made adaptable process models. The modelling and simulation results must be presented so that the management can see in the results the possibilities of making their planning, innovation and control processes more effective.

Keywords: transport system, mining, modelling, simulation

Introduction

Transportation of raw materials in the mining industry is an integral part of the rock extraction process. The technical level of transport systems must reach at least the level of other technological processes. The transport system cannot become an obstacle to the flow of raw material extraction. The transport system, the transport network and the organisation and management of transport significantly affect the efficiency of mining in mining operations [1]. When designing a new or changing an existing transport system in a mining company, it is necessary to ensure the existing or expected cargo turnover between the endpoints of the process, i.e. between any mining and processing facilities [2]. The nature of mining determines the diversity of mining transport systems, the amount of transport and handling means used, and the size of the area reserved for carrying out transport [1].

The efficiency of transport systems is a logistical problem. Currently, logistics solutions rely on automation, autonomous vehicles and data transfer between devices [3]. However, it should be remembered that the mining industry includes surface and underground mines. In underground mines, the problem of sufficient network coverage is encountered. In general, these new approaches are also expensive in terms of investment, which only suits some mining plants. In the territory of the Slovak Republic, small to medium-sized mining plants prevail, which do not see any perspective in such investments. An appropriate solution to make their transport systems more efficient is modelling and simulation [4].

Modelling and simulation are widespread procedures for assessing complex transport systems. Changes to the real system are often impossible or costly. Simulation allows the researcher to make possible adjustments and get feedback at the lowest cost [5]. Modelling and model creation is one of the fundamental cyber approaches to research, analysis, design and projecting systems. Modelling is a sequence of processes and activities in creating and verifying models. The requirements for the model are speed, accuracy, sufficient range and adequacy. Simulation is the method in which the investigated system modelled in software performs the modelled activity and results analysis. Experimenting with the model brings a lot of data and information that can be applied to the real system [6]. The advantage of simulation is excellent flexibility, lower demands on financial resources compared to real testing of objects, relatively long-term usability and does not affect ongoing business processes. On the other hand, the minus is

sometimes the need to comply with the limits of the simulation program, the need to quantify parameters, and the possibility of model failure in extremes [7].
In the science literature, it is possible to find several studies dealing with transport systems in mining plants. The studies and created models relate to underground and surface mining plants. They use various means of transport, from loaders and trucks, through belt transport to rail transport [1,5,8,9]. The authors of this paper participated in the preparation, modelling and simulation of mining plants located on the territory of the Slovak Republic. This paper aims to present a procedure that has proven itself in modelling Slovak mining plants and generalising some basic steps during modelling.

Modelling background

Initially, the initiative came from the management of the mine plant. However, after the conclusion of the agreement on modelling the transport system, the research team must take the initiative. First, the research team must have selected simulation software to perform the modelling. Subsequently, it must collect information to create a model step by step. The activity comes from the research team during the collection of information, but the plant management must be present and provide information, documents and discussions.
The information the research team should rely on are the fundamental documents related to the transport system, for example, the traffic order, the maps of the mine plant and the transport network. Discussions with the management and possibly the workers must supplement this basic information and possibly also the workers. These discussions complete the links between the system elements identified from the documents and maps. The research team is also recommended to have personal contact with the transport system, probably in the form of an excursion during mining. During such an excursion, discussions with competent persons bring additional information to documents that are important for modelling.

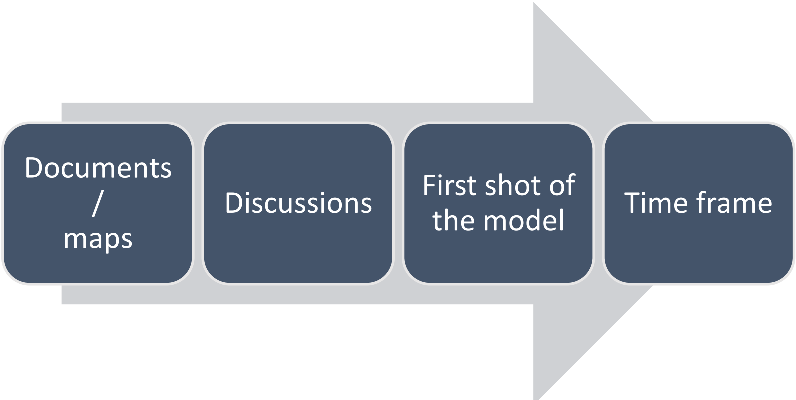


Fig. 1 Background process diagram

As shown in the diagram in Fig. 1, a first model can be created based on the information obtained from documents and interviews, with a high probability that this model will be modified. It is crucial to present this model to the management of the mine plant and consider each of their comments and suggestions. Most models also need the real transport system's time frames for proper functioning. The parameters during which the time frame is created must be recorded, and the measured time frame and the configuration of the parameters will be needed to verify the model in a later phase.

Basic processes models of mining transport systems

The simulation software ExtendSim 10 will be used in this and the following chapters. The software is one of the most basic options for modelling logistics systems. It is block software allowing both discrete and continuous simulation.

Every transport system consists of loading, transport and unloading. Let us consider that the software does not have preset blocks for these three processes. The blocks from the libraries will only be elements representing the activity, and the combination and relationships between them will form the links of the system. The activities we need to integrate into the three basic processes are best expressed by the Activity, Transport, Gate, Equation, Select Item Out, Holding Tank and Math blocks. With their correct composition, we can create a general and adaptable model of loading or unloading processes. Their task is to simplify and shorten the modelling of these processes. The model creator must only complete the specific loading or unloading specifications and correctly configure the blocks.

In the case of the loading process, it is essential to move the required amount at most the capacity of the means of transport from the pile of raw materials to the means of transport.

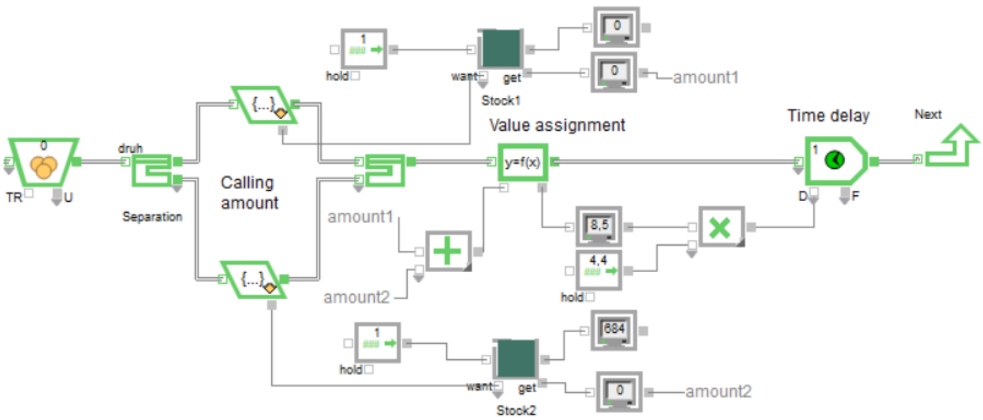


Fig. 2 Loading process

The general model of the loading process in Fig. 2 brings the means of transport to the loading point via Resource Item. It is possible to set the separation in Select Item Out and load from several places if necessary. The amount of raw material taken by loading from the Holding Tanks is calculated and brought into the equation, which changes the state of the means of transport to full. Of course, this process takes some time, and that delay is simulated using the Activity block.

The unloading process is similar to loading, but this time the material flow is directed from the means of transport to the pile of raw materials.

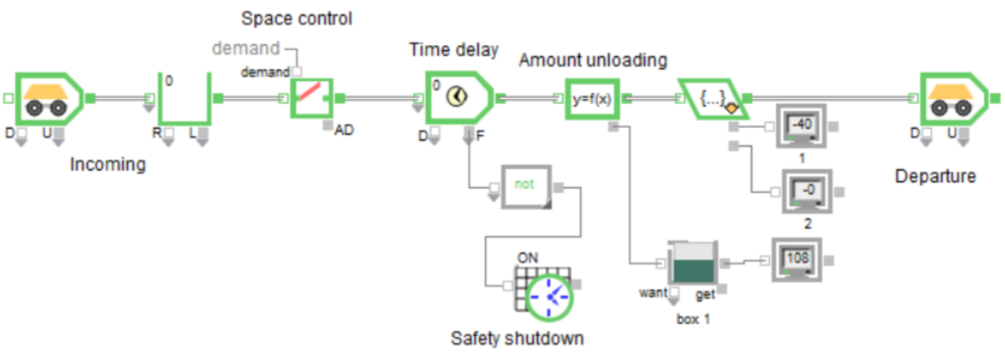


Fig. 3 Unloading process

Fig. 3 shows the unloading process, which first checks the free space in front of the unloading slot for the means of transport with the Gate block. It then simulates the unloading time while a safety guard is added to the Activity block, interrupting the unloading in case of violation of the unloading rules. Then the vehicle is marked as empty in the equation, and the capacity value is moved to the Holding Tank.

The last basic process is transport, whose composition and linkages depend highly on the modelled transport network. Creating a general model of the process is complicated because the transport networks are different and specific for each mining area. For modelling the transport process, it is recommended to use combinations of Transport and not Activity blocks, supplemented by flow branching blocks such as Select Item Out or Throw and Catch Item. In case of transport restrictions, it is also advisable to add Gate blocks. For a demonstration of the approach to the transport process modelling, Fig. 4 shows the transport model of a 6-plate surface mine with two-way traffic. The model does not include other processes, such as loading and unloading.

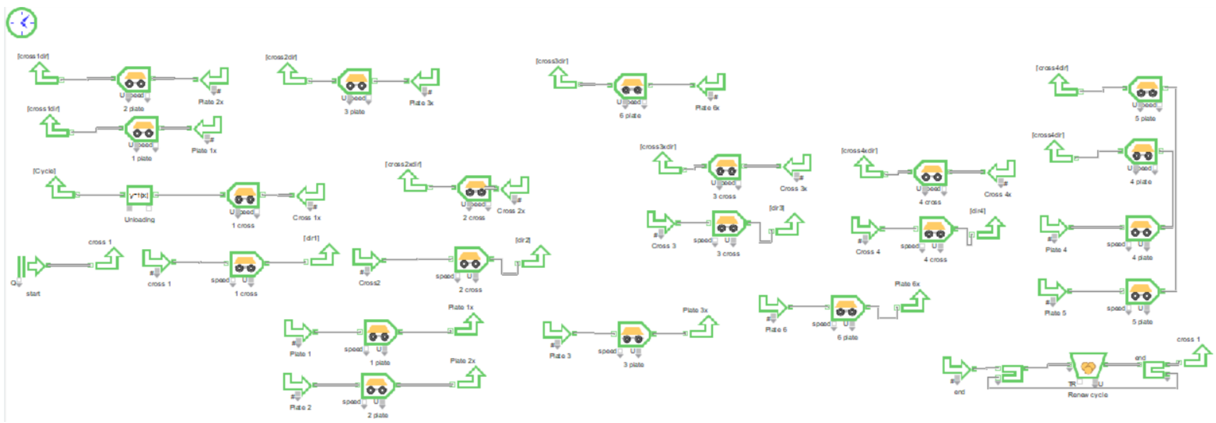
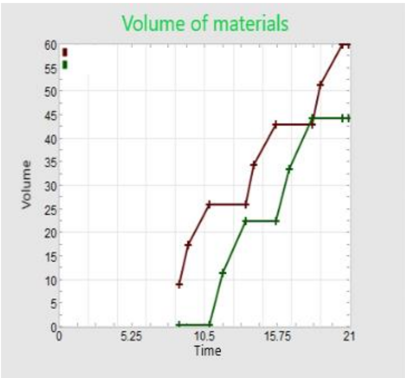


Fig. 4 Transport to the six plates of the quarry

The utilisation of simulation results

However, a stand-alone model and its simulation are something other than practice expects. Their purpose in modelling their transport systems is data and information with which they can increase the efficiency of their transport systems. Therefore, last but not least, an analysis of simulation results is necessary. The results of the simulations are in numerical or percentage form of the monitored statistics, but also in graphic form directly from the software.



	Time	Material1	Time	Material2
0	8,7735	8,5	8,7735	0
1	9,41483	17	10,9352	0
2	10,9352	25,5	11,8932	11
3	13,5968	25,5	13,5968	22
4	14,1282	34	15,7585	22
5	15,7585	42,5	16,6985	33
6	18,4022	42,5	18,4022	44
7	18,9335	51	20,5638	44
8	20,5638	59,5	21	44
9	21	59,5		

Fig. 5 Forms of simulation results

Fig. 5 is a graph supplemented with a table. Each block of the Chart library creates graphs and a table for the graphs. On the right of the picture is the result table of the Activity block. It collects data on block usage, block delay and block blocking.
Such results are used by the management of mining operations for operational planning and transport management. Based on the estimated amount of blasted raw material, they can determine the approximate duration of transporting it to the final location. Many small quarries use external transport. The carrier is usually paid per ton/kilometre. With the help of the model, they can quickly check the performance of external workers and find out how much they are using the load capacity of the vehicles. From the definition of simulation, it follows that thanks to the models, it is also possible to quickly verify changes in the transport system, for example, to test a new track, increase or decrease the number of loaders, implement another loading point, etc. Any modification of the transport system can be trusted with the model, even in the case of a worker's sudden sickness absence.

Conclusion

The transport system is an inseparable part of mining companies. To ensure the smoothness of mining, the management of mining companies must focus on the efficiency of the transport system, not only the mining process. Modelling and simulation are common means of evaluating the effectiveness of existing and non-existing logistics systems. Mining transport systems have a logistic character, and it is suitable to model them.
The procedure tested in two Slovak mining operations has proven itself for modelling mining transport systems. During modelling, it is necessary to pay attention to the correctness of the relations between the research team and management. Subsequently, it is necessary to secure fundamental documentation for the transport system and review everything with the management and competent workers. The research team should create a first shot of the model and discuss it with management. Subsequently, measuring time frames and modifying and configuring the model is necessary.
General and adaptable models of basic loading and unloading processes can also be integrated into the model. Their essence is to facilitate modelling and shorten its duration. Using a general model of one of the processes only requires adaptation to the conditions and specifics of the given system.
Transport system models bring operational planning, performance monitoring and verification of innovations and modifications to mining plants.

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MODELING AND SIMULATION WITH WLKATA EDUCATIONAL ROBOTS IN THE SPECIALIZED LABORATORY

Miriam PEKARCIKOVA–Peter TREBUNA– Michal DIC

Abstract: Education in the field of robotics and the use of robotic devices is of great importance for achieving competence in areas related to robotics. The use of real industrial robots as teaching and training devices, even though they have high accuracy and stability, is not suitable not only from an economic point of view but also from the point of view of weight and dimensions. Also, the internal structure and principle of the control system of industrial robots are confidential. The article deals with the issue of the importance and possibilities of using educational Wlkata Mirobots in laboratory conditions.
Keywords: Modelling, simulation, laboratory, education, robot.

Introduction

The motivation for implementing educational robots in research laboratories is primarily that they copy the functionality of a real robot, and it is also possible to work with its internal structure and logic. The disadvantage is that, even though researchers can learn how to control a robot, they do not have the opportunity to work with process algorithmizing. There are several options on the market for choosing educational robots, e.g. Wlkata Mirobot, Lego Mindstorms, mBot, Robobloq, Fanuc Corporation, Yaksawa Motoman, Abb, Kuga AG Kawasaki Robotics GmbH, etc. Educational robotics is included in the so-called STEM education (Science, Technology, Engineering and Mathematics), a teaching model designed for the joint teaching of natural sciences, mathematics and technology, in which practice takes precedence over theory.

The implementation of educational robots in teaching supports the development of:

- social competences: teamwork, discipline, compromise, adaptation, experimentation - trial and error, proactivity, self-esteem, self-evaluation, autonomy in solving problems,
- scientific and technological competences: knowledge of programming language, computational thinking, i.e. abstracting concepts, dividing a problem into small parts and proposing solutions that can be represented as a sequence of instructions and algorithms, scientific attitudes: the ability to search, acquire and handle information, interest in technological culture: through access to informatics, the Internet and multimedia content, creativity and innovation: development of creativity, finding innovative solutions beyond the scope of the first possible solution.

Educational robotics by applying Wlkata Mirobot

Wlkata Mirobot is a 6-axis mini industrial robotic arm manipulator developed by Beijing Tsinew Technologies Co., Ltd. This is a desktop Mirobot suitable for use as an educational device for various types of courses and research in the field of robotics. The advantage is the use of 3D printing technology to design, manufacture and manufacture the structural parts of the robot. It is equipped with a forward speed control algorithm to perform a smooth trajectory of movements. He uses the geometric method and the Euler angle transformation method to solve the inverse kinematics problem. It ensures high accuracy of movements of 0.2 mm.

Modeling and simulation of movements is ensured through software that can be controlled via computer, laptop and as an application via mobile phone and remote control via Bluetooth. Wlkata's offer of Mirobots and accessories makes it possible to use the modularity of individual elements and thus create a mini-line according to the requirements of researchers, university teachers and students. Wlkata's laboratory training platforms make it possible to implement an interactive and practical educational process, which has technologies such as PLC Bus-mastering, open-source API with support for further research in the field of robotics and the use of robotics in industry.

Robotic arm Wlkata Mirobot, Fig. 1, consists of a base, connecting frames, gear stepper motors and limit switch sensors. The robot has connecting frames and an appearance similar to an industrial robot and consists of six joints. A stepper motor with a reduction gear is installed on each joint.

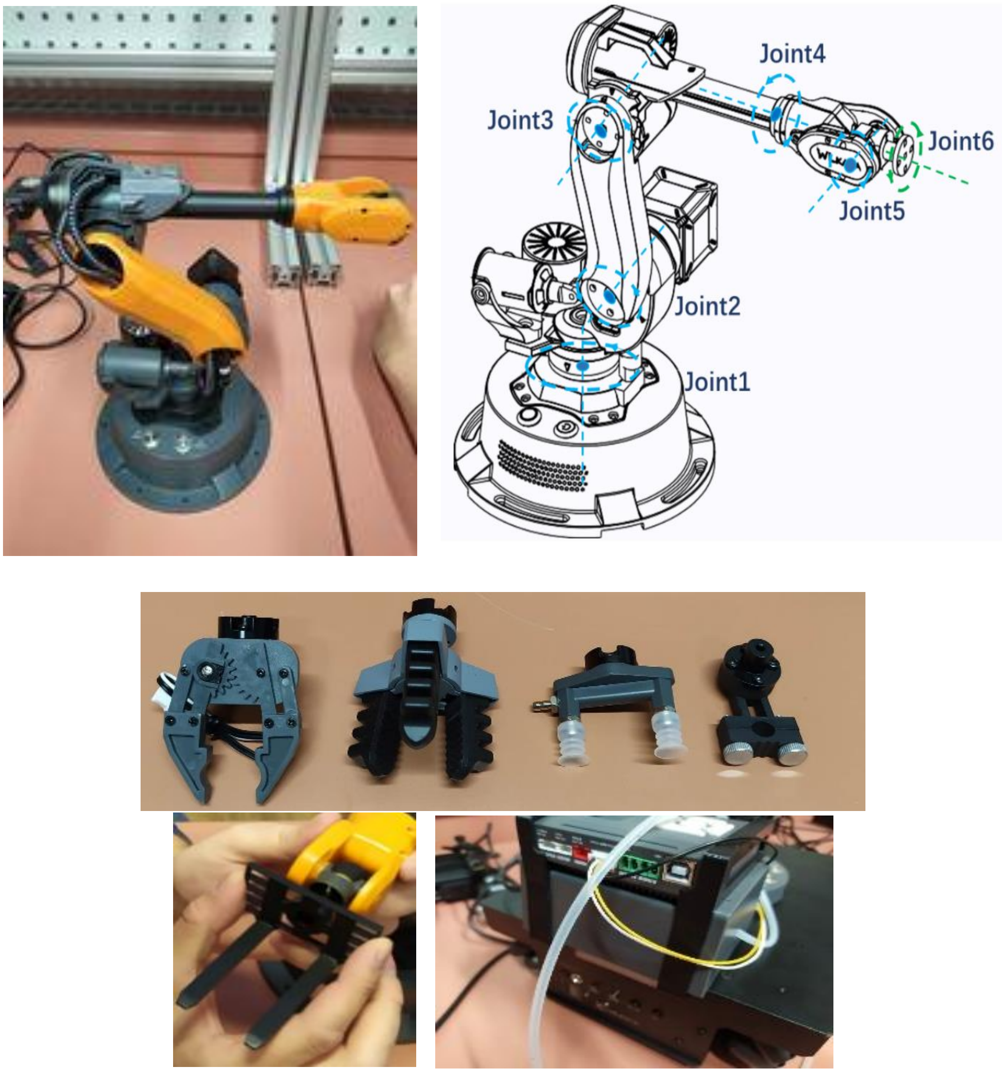

Fig. 1 Wlkata Mirobot with 6 degrees of freedom designation with replaceable attachments

Wlkata Mirobot can be programmed and controlled in the Wlkata Studio software environment, Control software, Fig. 2. The computer enables to realize the robot arm's single-axis movement function, Cartesian mode position control function, Teaching function, Blockly function, Python programming function and Drawing function. These functions of Wlkata Mirobot are designed for the implementation of qualified teaching or research in a specialized laboratory, Fig. 3., Fig.4 accessories for controlling the Wlkata Mirobot.

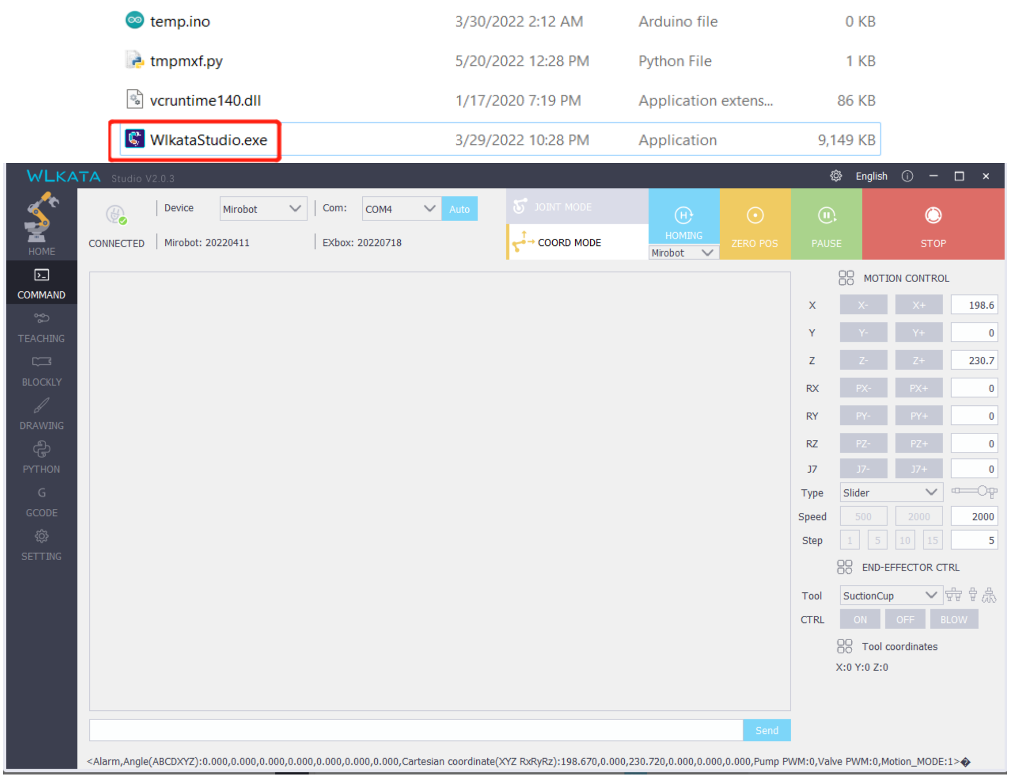

Fig. 2 Basic software environment for controlling Wlkata Mirobot

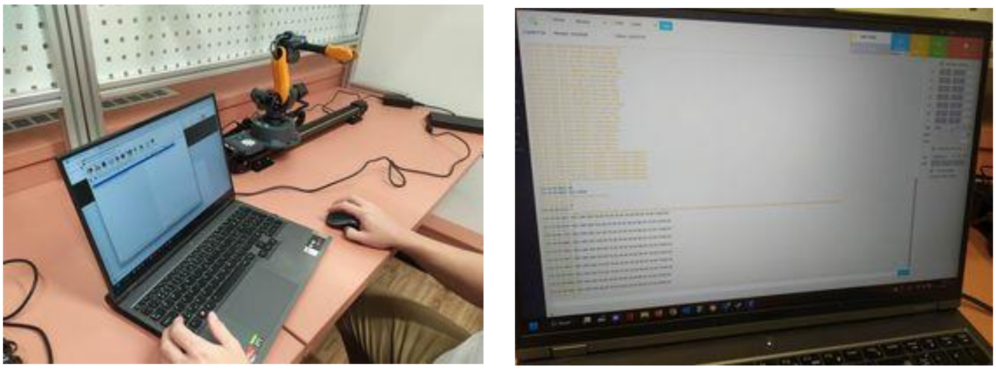

Fig. 3 Wlkata Mirobot control via Wlkata Studio software,

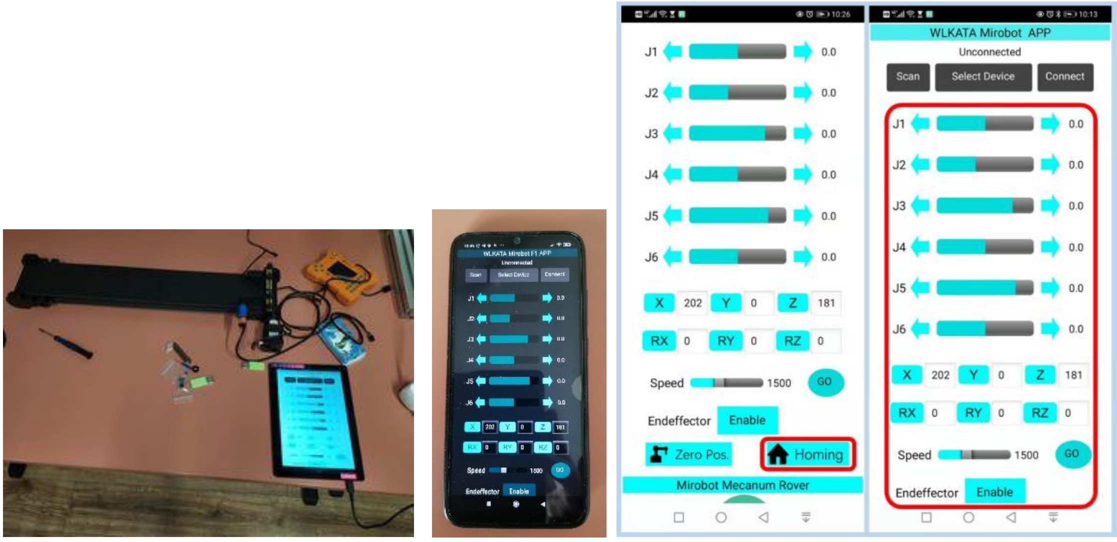

Fig. 4 Accessories for controlling the Wlkata Mirobot (controller of the robot, universal controller for the robot or lunar vehicle via Bluetooth, control of movements via an application on a tablet and phone)

Wlkata Mirobot represent dynamic elements for the creation of a physical model with the aim of creating a digital model of the production, or assembly line, Robot movements are programmed using our own Python programming language, and also through block diagrams Blockly function, which allows programming movements even without knowledge of the Python language. Wlkata Mirobot can be programmed for the necessary actions, which are then analyzed using simulation tools, tested and tuned with the possibility of connection with visualization through virtual reality, Fig. 5.

Fig. 5 Demonstration of work with Wlkata Mirobot in a specialized laboratory

Wlkata Mirobot hardware and software support allows you to design, create and test potential manufacturing and assembly processes. It is possible to create a dynamic system that can also be completed with elements from other manufacturers that allow connection via Arduino, Fig. 6. In this way, it is possible to create a functional line that will serve for research and development of other work possibilities in this direction. It is also possible to complete the physical environment through 3D printing of specific elements, Fig. 7.

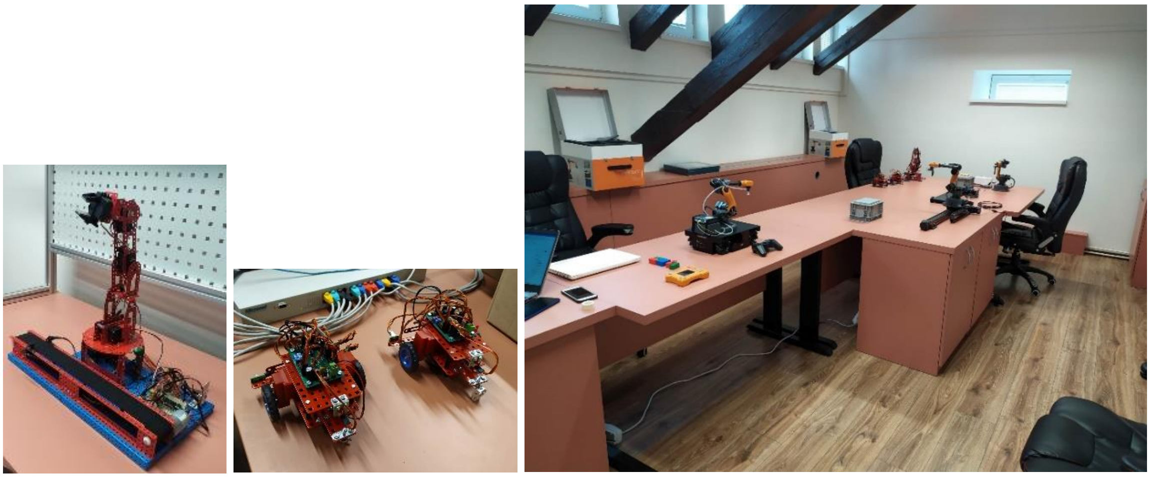

Fig. 6 Merkur kit - programmable mini line with the possibility of connection via Arduino

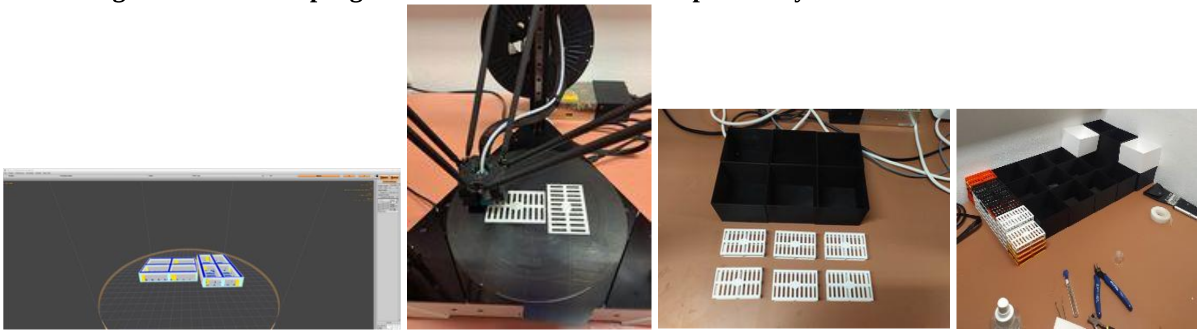

Fig. 7 3D printing of components for creating a physical model of processes

IOA Digital Twin for Wlkata Mirobot

Through the IOA Digital Twin platform, Fig.8., it is possible to test and acquire competences within the entire life cycle and personalization of orders. It is a software that supports a fully automated online ordering process, enables the realization of production order analyses, process planning, intelligent storage, flexible reconfiguration of production processes, laser engraving and three-dimensional assembly. It goes through the entire information pyramid from personalized orders on mobile phones, through digital data on the decision-making process at the MES/Manufacturing Execution System level to unattended production of digital production lines and remote digital SCADA/Supervisory control And Data Acquisition monitoring.

On the technological side, the information pyramid is important in merging the virtual and real worlds through data that is available in real time. Architectural changes in technical systems are aimed at networking and creating platforms based on cyber-physical elements in the system. With these influences and changes, the classic information pyramid expands:

- to horizontal cooperation - through IOT/Internet of Things/Internet of things and IOS/Internet of Services/Internet of services in the company's value chain,
- into vertical integration - through changes in the product architecture by introducing CPS/Cyber Physical Systems/Cybernetic-physical systems,
- the use of structured and unstructured data in real time in the design and optimization of the complex value chain of the company

Fig. 8 IOA Digital Twin - intelligent production integrated simulation and design platform

With increasing digitization in companies, interest in Cloud applications is increasing, which will contribute to the transformation of investment costs into operating costs through the so-called Outsourcing. The data are stored on central servers, from which it is possible to import, process, evaluate, use artificial intelligence software, etc.

Conclusion

Only the digitalization of production and products is not the only driving force of digitalization, it is also the possibility of networking technical systems in real time. Such an environment in connection with digitization creates a new business ecosystem. Creating partnerships, open networking of manufacturers with suppliers and customers, or even with competitors (opportunities for customer involvement in the product development process are opened up, i.e. certain activities are shifted to the customer) creates a basis for the development of new business models, and this can be considered revolutionary.

Advantages of creating a digital factory with Wlkata Mirobot in laboratory conditions:

- Reconfigurability: industrial robots supported by an experimental platform through their own configuration of control systems, simulation of digital twins, modeling of various robot activities (visual sorting, writing, drawing, laser engraving, etc.) form an integrated solution from basic programming, through applications, training to integrated development .
- Modular combination: each module is relatively independent and can be used individually or combined links, each module uses digital signage and the integration of an intelligent control unit.
- The system is easy to maintain, develop and train without losing industrial characteristics, supporting the development and application of industrial IoT professionals from the equipment level to the intelligent factory management level, which includes teaching, research and training of special technologies and professional core technologies in many professional fields such as electronic information, computers, industrial robots, etc.
- Digital twin: the system is equipped with a 1:1 digital twin system that allows you to create a real production line through virtual simulation and further test and optimize it in a virtual environment and then send verified information to the physical model.

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THE IMPACT OF INNOVATIVE PERFORMANCE ON THE COMPETITIVENESS OF COMPANIES

Dominika POPOVIČOVÁ

Abstract: Innovation has become a key determinant of a company's competitiveness in today's rapidly developing business environment. The aim of this paper is to examine the multifaceted relationship between innovation performance and companies' competitiveness. By examining the different dimensions of innovation and their impact on different aspects of competitiveness, this article provides insight into how organizations can strategically use innovation to improve their market position and sustainable growth. Based on a comprehensive review of professional literature and empirical studies, it presents the complex interplay between innovation and competitiveness, emphasizing the importance of supporting a culture of innovation, investment in research and development, and the use of technological progress. The findings underscore the critical role of innovative performance in shaping a company's ability to adapt, differentiate and thrive in today's dynamic business environment.
Keywords: innovation, innovative performance, company competitiveness

Introduction

In today's rapidly changing and evolving business environment, the impact of innovation on company competitiveness is considered a driving force for organizational success. Innovation refers to the creation and implementation of new ideas, products and strategies, and innovation has become an essential catalyst for companies trying to stay relevant, capture market share and secure sustainable growth. [1] Markets are increasingly dynamic and customer preferences are constantly changing, and companies' ability to innovate becomes a strategic advantage. Thanks to innovation, companies can manage the challenges of the modern business environment and thrive in it. The main aim of this paper is to delve into the complex and multifaceted relationship between innovation performance and companies competitiveness. Through a comprehensive analysis of the various dimensions of innovation and their direct impact on different aspects of competitiveness, organizations can strategically use innovation to improve their market position, achieve sustainable growth and secure a significant advantage in an ever-evolving business landscape. [2]

Dimensions of innovative performance

Product, process, organization and marketing are among the four key dimensions of innovation that have a significant impact on the company's competitive ability. Product innovation is at the core of a company's ability to continually engage its audience. It includes the development and introduction of new goods and services that not only meet but exceed customer expectations. [1] Process innovation revolves around optimizing internal operations and workflows. Streamlining processes, automatization of routine tasks and increasing efficiency are becoming the basic pillars of operational excellence. Companies that engage in this dimension of innovation reduce costs and shorten time to access market, supporting a dynamic business environment. [3]

Connection between innovative performance and the competitiveness of the company

The connection between innovative performance and the competitiveness of the company is currently proving to be a very strong and important basis for the success of the company on the market. Innovation plays a key role in enabling companies to navigate and respond to changing market conditions. [5] By fostering a culture of continuous improvement and evolution, innovative companies are better equipped to quickly adapt their strategies in response to disruptions, emerging trends, and changes in consumer preferences. Innovation drives companies towards customer satisfaction. By proactively identifying and meeting new customer needs, innovative companies not only retain their existing customer base, but also attract new clientele. Through innovation, companies can design new ways to anticipate and exceed customer expectations, building strong and lasting relationships. [3]

Several leading companies have used the power of innovative performance to gain significant competitive advantage. Netflix's disruptive innovation in the entertainment industry, moving from a DVD rental service to a global streaming platform, is an example of how innovative business models can redefine entire markets and customer behavior. Similarly, Tesla's groundbreaking advances in electric vehicles and renewable energy solutions have positioned the company as a pioneer in the automotive industry. Apple's introduction of the iPhone revolutionized the mobile phone industry and allowed the company to maintain a competitive edge by constantly updating and reinventing its product offering.

The role of Research and Development (R&D)

Investments in research and development (R&D) are necessary to support the innovative performance of companies. Investments in research and development create innovation, drive technological progress, enable businesses to experiment with new ideas and push the boundaries of existing knowledge. By devoting resources to research and development, companies can proactively address challenges, seize opportunities and become leaders in their industries. [4]

Investments in research and development yield a valuable by-product: intellectual property (IP). Patents, trademarks, copyrights, and trade secrets created through research and development initiatives provide companies with a competitive advantage by protecting their innovations from imitation. Companies with extensive intellectual property portfolios can assert their position in the market, deter competitors and monetize their inventions. Examples of innovation strategies based on research and development include Procter & Gamble (P&G). P&G's Connect + Develop program supports open innovation by collaborating with external partners to co-create innovative products. Through R&D partnerships, P&G leveraged external expertise and expanded its product offerings. Microsoft's extensive investment in research and development has resulted in pioneering software products such as the Windows operating system and the Office suite. [4]

Leveraging technological advances for innovative performance

In today's business environment, technological advancements have proven to be a powerful enabler of innovative performance that has revolutionized the way companies operate and compete. This section delves into the profound impact of technological breakthroughs, including digitization, automation, and artificial intelligence (AI), in supporting innovation efforts. It also explores how companies can strategically integrate these new technologies to gain a distinct competitive advantage.

Digitization enables companies to collect and analyze vast amounts of data, facilitating informed decision-making and uncovering valuable insights. Through digital platforms, companies can interact directly with customers, enabling real-time feedback and co-creation of products and services. [6]

Automation technologies streamline and optimize routine tasks, freeing up human resources to focus on more creative and strategic activities. Robotic process automation (RPA) and machine learning algorithms increase efficiency, reduce errors and speed up processes. This allows companies to allocate resources to innovation-based initiatives that create greater value.

Artificial Intelligence (AI) technologies, including machine learning and natural language processing, enable companies to extract meaningful patterns from data, automate complex tasks, and predict future trends. AI-powered analytics enable companies to tailor products, services and experiences to individual customer preferences, fostering deeper connection and increasing competitive differentiation.

The integration of technological advances such as digitization, automation and AI is key to fostering innovative performance and securing competitive advantage. By leveraging these technologies to increase agility, customer focus, predictive insights, creativity and risk reduction, companies can position themselves as leaders in innovation and achieve sustainable growth and success. [7]

Conclusion

In conclusion, it is necessary to point out that the research of the relationship between innovative performance and the competitiveness of the company is essential for a company that wants to develop its potential on the market. The submitted article has comprehensively explored this dynamic relationship and has shed light on how innovative performance serves as a key determinant of a company's ability to thrive, adapt and excel in today's rapidly evolving markets. Through a multifaceted examination of innovation dimensions—including product, process, organizational, and marketing innovation—it has been shown that innovation performance is a natural driver of sustainable competitive advantage. By consistently introducing new products, optimizing internal processes, supporting agile cultures and pioneering marketing strategies, companies are paving the way for differentiation and market leadership. The article further pointed to the strengthening of the innovative capabilities of the enterprise through technological advances such as digitization, automation and AI. Innovative performance leads companies towards a future where adaptability and creative dynamism are the names of success. As case studies worldwide show, visionary companies that embrace innovation as a strategic imperative achieve not only market resilience but transformative market disruption. Ultimately, this article underlines that the impact of innovation performance on companies' competitiveness goes beyond mere correlation – it is a strategic imperative, a catalyst for evolution, and evidence of an unyielding entrepreneurial spirit in the face of change.

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IDENTIFICATION OF RECYCLABLE CATALYSTS

Martin Straka – Peter Kačmáry – Jakub Kovalčík

Abstract: The presented article focuses on the possibilities of recycling three types of catalysts. These catalyst types will undergo examination, measurement, and analysis with the aim of identifying which of these catalysts contains the necessary number of precious metals (PGM - Platinum Group Metals). PGM metals are among the rarest and most challenging-to-obtain elements on Earth, carrying a high risk of supply shortage. Nevertheless, they are crucial for the European Union (EU) and the automotive industry. Not every catalyst used in the market is suitable for recycling due to the absence of these precious metal particles.

Keywords: catalyst, recycling, PGM, materials, method

Introduction

In the dynamic environment of modern industry and technological advancement, the concept of sustainability has emerged as a primary aspect. As societies strive to achieve a harmonious balance between economic growth and environmental care, the critical role of recycling processes becomes increasingly evident. Among these processes, catalytic recycling stands out as a key player on the path to a more sustainable future.

The necessity for catalysis recycling becomes even more apparent when considering the intricate composition of modern catalysts. Numerous industrial catalysts are designed with complex structures that incorporate rare and precious metals like platinum, palladium, and rhodium, collectively known as Platinum Group Metals (PGMs). These metals, acclaimed for their exceptional catalytic properties, confront a challenging paradox. While propelling the development of sustainable technologies, their scarcity and associated geopolitical intricacies pose significant supply chain risks. This dual nature of PGMs intensifies the urgency to implement effective recycling procedures that ensure the responsible and efficient utilization of these valuable resources.

The need for catalytic recycling goes beyond the scope of resource conservation. It deeply resonates with the global effort to reduce the ecological footprint of various industrial sectors. Given that catalytic processes are an integral part of sectors such as energy production, transportation, and chemical manufacturing, the effective recycling of catalysts contributes to reducing energy consumption, lowering emissions, and minimizing waste generation. These outcomes align with international sustainability goals and regulatory frameworks aimed at mitigating climate change and promoting a circular economy [1].

Prepare of identification of sustainable catalyst

The identification of each used catalyst depended on the container code. The main characteristics of each catalyst included the car model and catalyst type. The type of catalysts was verified based on the metal content after chemical analysis [2].

Tab. 3 Identification of 3 catalysts on market [3]

Number	Canister code	Model Car
1	13106917	Opel Astra H
2	8200358551, C114	RENAULT ESPACE, 2200CC, DIESEL
3	3B0131701Q, 8D0178E, GLH	AUDI A6, 2400CC, DIESEL

Each catalyst was disassembled and de-canned to remove the metal container and obtain the ceramic catalyst, which was prepared for physic-chemical characterization. The decanting process was conducted carefully to prevent the fracture of the ceramic monolith inside, allowing the evaluation of weight and dimensions [2].

Tab. 4 Dimension of catalyst [3]

Number	Weight, g	Height, cm	Diameter, cm
1	952.30	9.7	20.1
2	1026.75	14.4	10.7
3	573.50	11.9	11.4

The acquired dimensions of each catalyst were measured according to their shape. For cylinder-shaped catalysts, weight, height, and diameter were measured. Each ceramic catalyst was pre-processed for microscopic analysis and elemental analysis (XRF). The pre-processing involved steps of grinding, milling, and sieving to reduce the particle size below 250 µm. During the grinding phase, small pieces were taken from each catalyst, which underwent analysis by optical microscopy for cell observation and measurement of their dimensions [2].

Analysis through Optical Microscopy

In the context of analyzing three different catalysts used in the study, an optical microscope from the AmScope ME520 (Figure 1) series was employed, along with the corresponding software. The data was acquired at a total magnification of 125x. A detailed description of the obtained information regarding each catalyst follows [2].

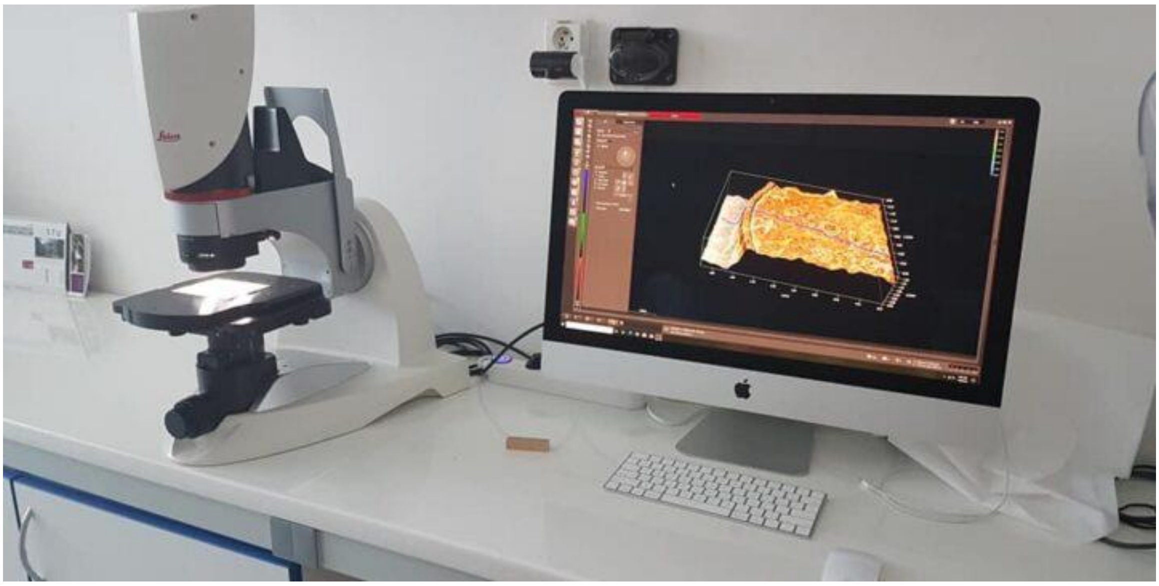

Figure 2 AmScope ME520 [5]

Process of identification of sustainable catalyst via optical microscopy

- **Catalyst number 1:**

Two minor fragments were gathered (Figure 2) from the exhausted catalyst for the purpose of capturing images from various regions under the optical microscope, wherein the density of cells and the thickness of the ceramic monolith walls were assessed [2].

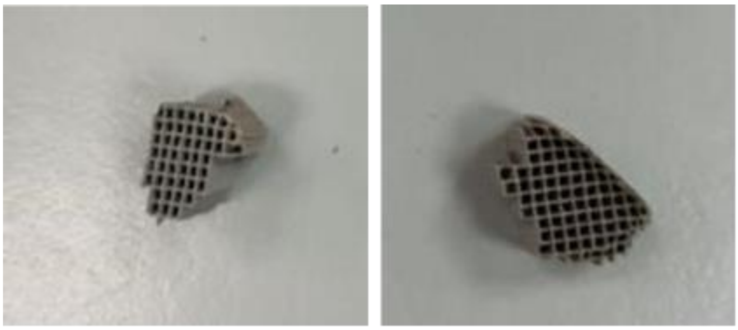

Figure 3 Pieces from catalyst number 1 [3]

Utilizing the optical microscope images, the density of cells and the thickness of the monolith's washcoat were evaluated. The findings derived from the optical microscope revealed an estimated cell density of around 527 cells per square inch (cpsi). Furthermore, measurements and calculations yielded a cell wall thickness of 0.193 mm and a washcoat thickness of 0.049 mm.

- **Catalyst number 2**

To gain visual insights from diverse regions under the optical microscope, two minor fragments were gathered (Figure 3) from the exhausted catalyst number 2. This facilitated the assessment of cell density and ceramic monolith wall thickness. The images obtained through the optical microscope were also utilized to gauge the cell density and washcoat thickness of the monolith. Specific regions (Figure 4) were chosen to quantify the catalyst's cell density [3].

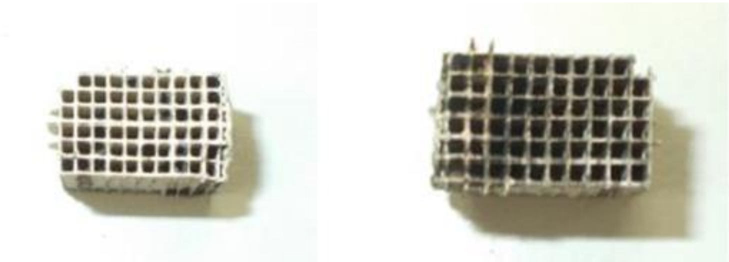

Figure 4 Pieces from catalyst number 2 [3]

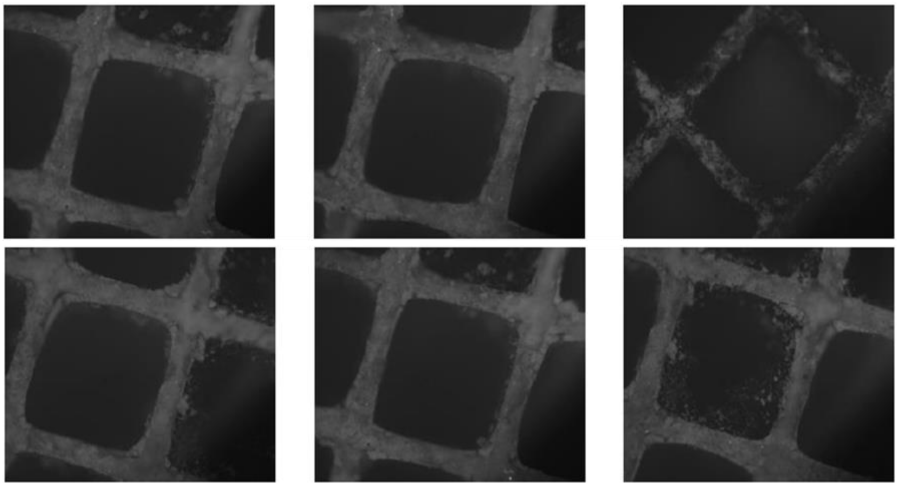

Figure 5 Optical microscope images from catalyst number 2 [3]

- **Catalyst number 3**

To capture a variety of perspectives under the optical microscope, two minor fragments were gathered (Figure 5) from depleted catalyst number 3. This procedure aimed to measure the cell density and the thickness of the ceramic monolith's walls. The cell density and the washcoat thickness of the monolith were determined based on the images obtained through the optical microscope. Specifically designated regions, (Figure 6), were chosen to quantify the catalyst's cell density [3].

Figure 6 Pieces from catalyst number 3 [3]

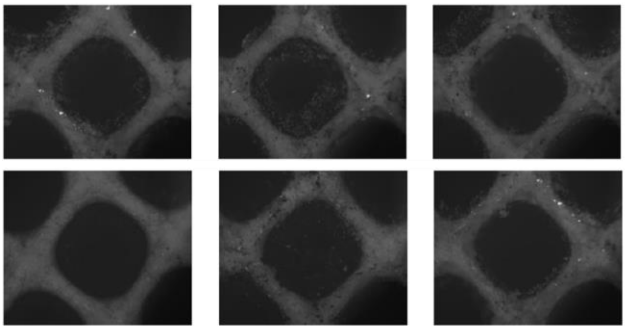

Figure 7 Optical microscope images from catalyst number 3 [3]

Chemical analysis

In the realm of elemental analysis, the importance of preliminary processing and accurate sample selection cannot be overstated. For every ceramic catalyst, an individual procedure involved milling, ensuring that 80% of the sample achieved a particle size below 250µm, accomplished via a knife mill (Figure 7). The particle size of each sample was subsequently verified with sieves tailored for sizes below 250µm [5].

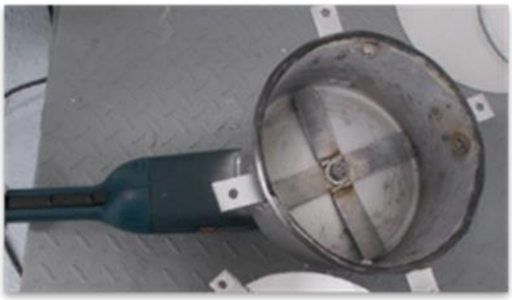

Figure 8 Knife [3]

Each sample underwent a process of homogenization and was subsequently divided into four distinct sections. To yield more comprehensive and representative outcomes, two minor samples were obtained. These were subsequently subjected to drying in a BINDER oven (120°C, 2 hours) (Figure 8), in preparation for XRF analysis aimed at quantifying the content of Platinum Group Metals (PGMs) [5].

Figure 9 Dryer [6]

X-ray Fluorescence (XRF) analysis

The loading of PGMs was ascertained using X-Ray Fluorescence spectroscopy. XRF analysis, a method characterized by accuracy, speed, non-destructiveness, and repeatability, eliminates the need for chemical preparation. Consequently, chemical reagents are unnecessary, thereby minimizing costs. The XRF spectrometer (Vanta Olympus 2017, Waltham, MA, USA) (depicted in Figure 20) comes with an inherent calibration from the manufacturer, allowing precise measurement of Pt, Pd, and Rh in used catalysts with average PGM concentrations of 1000ppm, 1700ppm, and 300ppm, respectively. Despite the existing calibration of the X-ray Fluorescence (XRF) analyzer, conducted an additional calibration to enhance the precision of XRF measurements. Through this supplementary calibration, Pd was calibrated within a loading range of 1270-2730ppm, Pt within a range of 614-2760ppm, and Rh within a range of 237-322ppm. The PGM content of the two minor samples from each catalyst was gauged, and their average was computed (Tab.3). The homogeneity of the catalyst samples was verified through these measurements [7].

Calcination process

As previously noted, the microscopic examination revealed the presence of organic residues within the structure of the catalytic converter. Consequently, a calcination procedure was undertaken on small-scale samples to quantify the mass of these organic deposits within each catalyst. Additionally, the calcined samples were subjected to XRF analysis to evaluate how these organic compounds influenced the detection of PGM concentrations. The quantification of organic deposits was based on the comparison of sample mass before and after the calcination process, conducted at a temperature of 750°C for a duration of 5 hours. The impact of calcination was evident through visual observation, particularly by noting the color alteration in the various samples [7].

Conclusion

In summary, a total of 3 used catalysts were examined for the purpose of their comprehensive physicochemical characterization. This characterization encompassed catalyst identification, preprocessing, and XRF analysis. These steps aimed to prepare the samples for chemical analysis and determine the content of PGMs (platinum, palladium, rhodium). Calcination was performed to identify potential organic residues in each sample. The samples underwent XRF analysis before and after calcination to assess the impact of organic compounds on PGM detection.

Regarding the ultimate identification of the provided used catalysts, those containing rhodium and platinum or/and palladium were classified as Three-Way Catalysts (TWC). Conversely, catalysts primarily containing platinum or/and palladium were mostly identified as Diesel Oxidation Catalysts (DOC). Nevertheless, spent catalytic converters with low concentrations of platinum or/and palladium could potentially be labeled as Dual-Function Catalysts, considering additional information such as the vehicle model and manufacturing year [7].

Tab. 5 Conclusion table [3]

Number	Pt, ppm	Pd, ppm	Rh, ppm
1	-	1945	348
2	620	-	-
3	2434	-	-

As a result of this detailed analysis, the following research findings were obtained.

- Only catalyst number 1 is identified as a suitable for recycling thanks to the values of Pd and Rh.
- Only Pt was detected in the other catalysts [7].

Acknowledgement
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Review process: peer reviewed process by two reviewers.

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SIMULATION MODEL OF THE PACKAGING PROCESS

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Abstract: Proper packaging reduces logistics costs. It must reach the optimal size and adapt to handling, transport, and storage techniques. This paper aims to present a simulation model of the selected packaging process. The simulation model of the packaging process was created in the Plant Simulation program, Tecnomatix. The result of the simulation is the number of foil-wrapped pallets. Other results are available, such as the ongoing number of loaded pallets for individual products and the maximum number of boxes in individual buffers during the simulated time. The simulation model is suitable, e.g. for predicting the number of workers for manual packing, determining the required number of forklifts for moving pallets...
Keywords: packaging, box, simulation, model, results

Introduction

Current trends indicate continuous improvement in production and logistics in enterprises. An essential element in these areas is the packaging of finished products. Proper packaging reduces logistics costs, and it must reach the optimal size and adapt to handling, transport and storage techniques.

Packaging is a term for a material that has the nature to be used for containment, protection, handling, delivering, and presenting goods from the producer to the consumer or user, as well as preserving the product [1].

After the end of the production process, the task of packaging is to create conditions for economical storage, transportation, handling, and product protection from the effects of the external environment. However, the packaging also ensures that the consumer and society's hygienic, aesthetic, and ecological requirements are met. Packaging is typically viewed as being either consumer, focused primarily on marketing, or industrial, focused on logistics.

The paper authors, Escursell S. et al., reviews the evolution of packaging over the last century by compiling scientific literature on e-commerce packaging, focusing on its environmental side [2]. A systematic literature review of studies done over the last 18 years to generate a greater understanding of the work done in the field of sustainable packaging in supply chain management is presented by authors Meherishi et al. [3].

The packing process includes a sequence of work operations necessary for packing goods, from the supply of empty boxes, pallets and goods to the packing place, through the own method of packing, to the creation of packaging units for storage and transport.

A packaging system comprises three components: primary, secondary, and tertiary. Primary packaging is in contact with the product. Secondary packaging contains primary packages, and tertiary packaging contains secondary packages. Assessing packaging as a system emphasises that the performance of a packaging system depends on each packaging component and the interactions between them all (Hellström and Saghir, 2007) [4].

This paper aims to present a simulation model of the selected packaging process. Simulation as a scientific method is now widely used in research and practice. Currently, they are used for the creation of simulation models in various areas (transportation systems, handling systems, production systems, urban planning systems, logistics systems, ecological problems, etc. [5,6,7]), several simulation tools such as Witness, Tecnomatix Plant Simulation, Extend, and others.

Methodology - Application of computer simulation

Simulation is a research method where we replace the object of study with a model. We conduct experiments on the created model to accumulate and use information about the real system later. The simulation of the selected logistics activity consists of several steps. The following points describe the basic steps shown in Fig. 1[8].

A: Identification of the system and its graphical interpretation for the needs of a simulation model creation. A graphical representation of the system is created.

B: Creating a simulation model by the selected simulation tool. Currently, simulation packages are used for creating a simulation, which facilitates creating a model. Their advantage is graphic symbolism, creation of statistics, 2D or 3D animation, and flexibility when changing the model itself and the input data.

C: Simulation of experiments in which the input parameters of the simulation model are changed. The task of the experiments is to see changes in the output parameters of the system.

D: Analysis of simulation results and recommendations. Outputs from individual experiments (statistical parameters, performance parameters and graphical outputs) are used for analysis and behaviour of the system under changed conditions. These results need to be interpreted and used correctly.

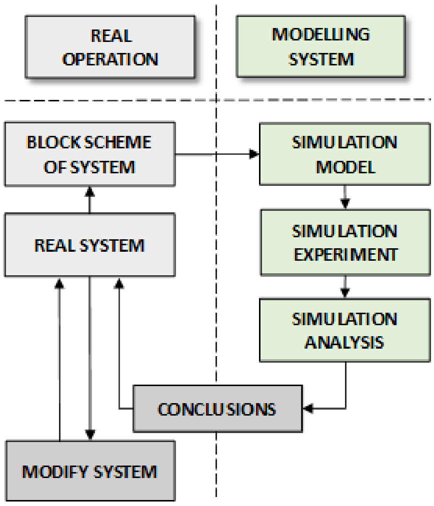

Fig. 1 Simple modelling methodology [8]

Results

The simulation was applied to a manufacturing company's selected packaging (palletising) workplace. The flow chart of activities at the packaging workplace shows in Fig. 2.

At the entrance to the packaging workplace, the finished products are packed in cardboard boxes - 7 types with different parameters and are marked with a 2D/QR bar code, which is the output of the production lines. These boxes are moved from the production line using roller conveyors for scanning. After reading the barcode on the box, it is moved to one of the seven positions with the help of a pneumatic pusher. The finished product is moved to the destination using a vertical roller conveyor at the given position. At this point, the quality control of the packaged product (cardboard box) is performed. The finished product's packaging quality is assessed by visual inspection, which the operators of the packaging workplace carry out. If the finished product meets the requirements, it remains on the conveyor. If the finished product does not meet the requirements, it leaves the conveyor and is moved to a place for products that do not meet the required packaging quality, from where the authorised operator takes it for repackaging.

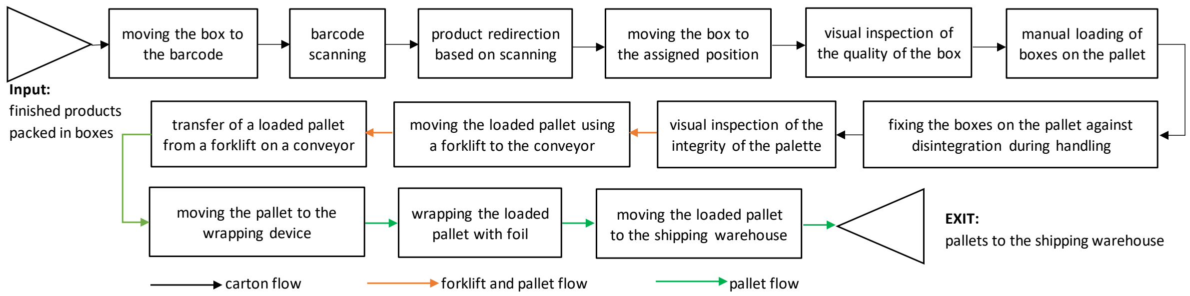

Fig. 2 Simple scheme of activity of activities at the packaging workplace

Thus, only finished products suitable for dispatch are grouped on the conveyor. These are manually removed by the operator and placed on the pallet in the required number of layers based on the packaging regulations. After stacking the pallet, the cardboard boxes are fixed using a fixing element to prevent the stacked pallet from falling apart during further handling. The operator visually checks the integrity of the pallet and instructs the forklift driver to move it. The forklift driver moves the pallet and places it on another roller conveyor at the packaging workplace. This includes a wrapping device where the pallet is wrapped in foil and transported to the sales warehouse on an automated conveyor, where the packaging (palletising) process ends.

The packaging system comprises devices: segments of roller conveyors, pneumatic pushing units, and wrapping equipment. In addition to these technical devices, the system is supplemented by calls and operators. The system comprises parts that are performed automatically, mechanised and manually.

Process analysis was performed to create and fill the simulation model with relevant data. Analysis was done by observation and measurement. The intervals at which the boxes with finished products entered the conveyor, the time the operator placed the box on the box, and the wrapping time were measured.

The obtained values of intervals and number of boxes on the pallet are shown in Table 1. The average time for manual transhipment of a box is 10 seconds, and the time for wrapping a pallet on a wrapping machine is 150 seconds.

Tab. 6 Data from analysis

Finished products (FP)	Box entry interval from the production line to the conveyor belt (sec)	Number of boxes on the pallet
FP 1 (Box1)	5	473
FP 2 (Box2)	5	147
FP 3 (Box3)	4	160
FP 4 (Box4)	4	250
FP 5 (Box5)	4	60
FP 6 (Box6)	10	16
FP 7 (Box7)	8	40

The simulation model of the packaging process described above was created in the Plant Simulation program, Tecnomatix. This program simulates, visualises, and analyses various production systems and logistics processes to optimise material flow and resource utilisation. The simulation model is created using standard blocks of the program Plant Simulation, Fig. 3. Print screen of the created simulation model shows in Fig. 4.

EventController	Source	Conveyor	Angular Converter	Transfer Station
Buffer	Track	Station	Drain	Chart

Fig. 3 Used blocks

An "EventController" was inserted as the first block. The EventController coordinates and synchronises the events during a simulation run.
Blok "Source" produces MUs in a single station. The block generates boxes with finished products in the model. The seven blocks were inserted, each generating one type of product - a box.

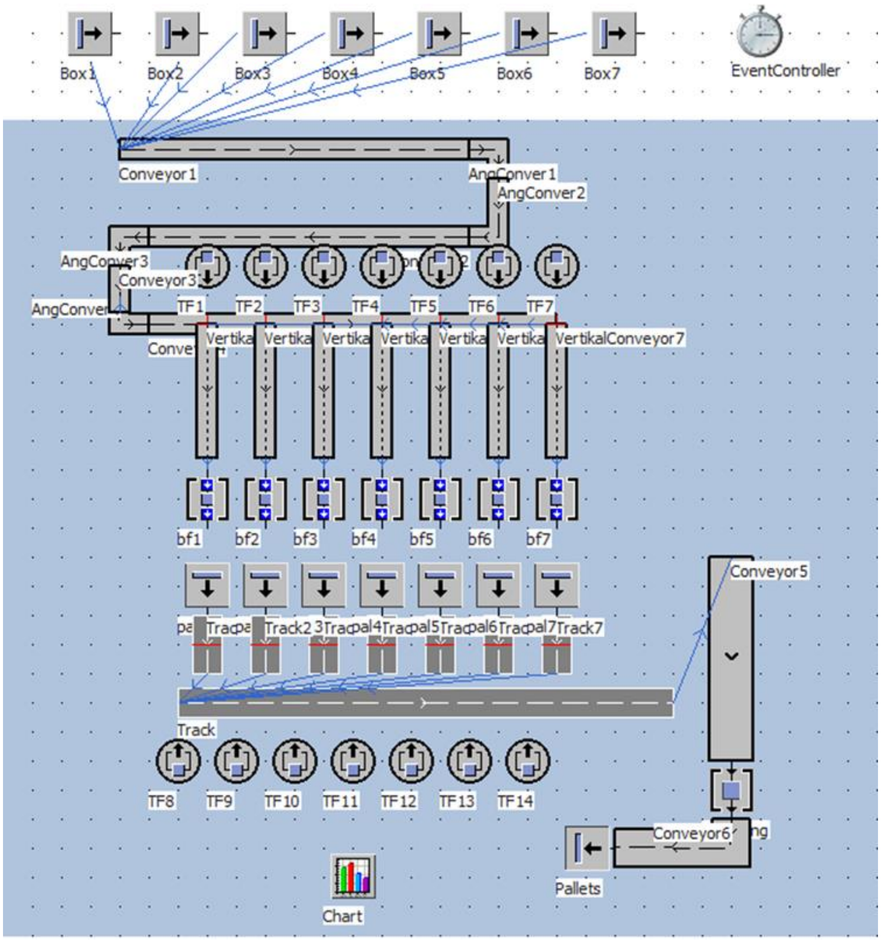

Fig. 3 Print screen of the created simulation model

Subsequently, a transport route was created using the "Conveyor" and "Angular Converter" blocks. The parameters of length, width and conveyor movement speed were set in these blocks. The "Transfer Station" block represents a barcode reader and a pneumatic pusher that changes the direction of the box from the main conveyor route to the given positions. The seven blocks were inserted for individual finished products and positions (TF1-TF7).
Block Buffer (1-7) (block operating on the FIFO principle) represents the queue of boxes that need to be stored on pallets.

The other "Transfer Station" blocks (TF8-TF14) simulate operators' manual loading of boxes from a given position to a pallet. Loading starts as soon as the part and means of transport are ready.
The loaded pallet, the "Source" block, is the input unit for further activities - moving along the transport path created by the block “Track” by a forklift and then along the conveyor to the wrapping machine - the block "Station".
The foil-wrapped pallet is the output of the packaging process – the block “Drain”.
Several experiments were performed on the given simulation model. This paper shows results for a simulated time of 3 hours and 15 minutes, the time of half the work shift. Entry to the boxes lasted 3 hours and 10 minutes. The obtained results are in Table 2.

Tab. 7 The obtained results

Finished products (FP)	Input - number of boxes	Number of loaded boxes on pallets	The number of boxes in the buffer after the end of the simulation	Number of loaded pallets
FP 1 (Box1)	885	885	0	1
FP 2 (Box2)	885	885	0	5
FP 3 (Box3)	885	885	0	3
FP 4 (Box4)	884	882	2	6
FP 5 (Box5)	884	780	104	13
FP 6 (Box6)	881	704	177	44
FP 7 (Box7)	881	840	44	21

During the simulated time, 6186 boxes were entered into the process. The 92 pallets were processed on the wrapping equipment and moved to the sales warehouse. The three pallets were partially loaded at the end of the simulated time. The 18 pallets were on the way to the wrapping equipment. When the simulation ended, one pallet was in the wrapping process. Fig. 4 shows the percentage utilisation of individual "Transfer Station" (TF8-TF14).

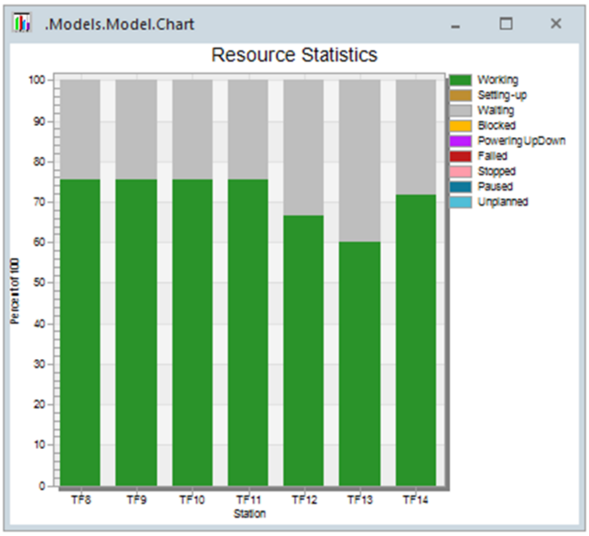

Fig. 4 The percentage utilisation of "Transfer Station" (TF8-TF14)

Conclusion

The simulation model simulates the flow of boxes with finished products to the place where they are loaded on pallets and then moving pallets to the wrapping device, wrapping them in foil and moving them to the sales warehouse. The result of the simulation in the experiments is

the number of pallets moved to the dispatch warehouse. Other results are available, such as the ongoing number of loaded pallets for individual products and the maximum number of boxes in individual buffers during the simulated time. The simulation model is suitable, e.g. for predicting the number of workers for manual packing, determining the required number of forklifts for moving pallets...
On the mentioned model, after changing the input data, it is possible to simulate various scenarios of the packaging process or add additional loading stations and wrapping equipment. Simulation of other scenarios will be the subject of further research.

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DESIGNING AND SIMULATING ROBOTIC WORKPLACES USING VR AS AN INOVATIVE APPROACH IN BUSINESS PROCESSES

Simona ŠPIRKOVÁ

Abstract: Virtual reality and robotic workstation can definitely be considered as an important technology that could and should be used in the industry in all different environments. Today, robotic workplaces are becoming a standard part of every smart factory and company all around the world. What these trends are, what they mean and what practical applications and advantages are connected with them is the subject of this article.

Keywords: designing, simulating, robotic workplace, VR, trends and innovative approaches

Introduction

Humanity is currently going through a historic period. We are currently on the cusp of unprecedented discoveries and opportunities that have ever existed, and they are growing almost on daily basis. All of this is a result of the technology we have and are constantly developing. As technology evolves, so does everything else, including humanity itself. This adaptation comes from established trends that are changing our society. The approach of companies and how quickly it responds or adapts is itself a key factor that we can consider as an indicator of a company's future prosperity and competitiveness. Logistics has always been and will be influenced by market trends, among which today we can include the implementation and integration of smart and autonomous transportation systems, which has a significant impact on the supply chain. Today, robotic workplaces are becoming a standard part of every smart factory and company all around the world. These companies use a combination of different concepts, methods, techniques and technologies to improve process efficiency. However, all of this is only possible thanks to the advanced technology and artificial intelligence available to us nowadays. Today, the market itself is still significantly affected by the pandemic and post-pandemic waves, which brings challenges of changing and growing demand and rising customer expectations. The demands of globalization economic pressures are forcing all businesses to become more flexible and efficient, meaning that only those that are adaptable will survive in the coming years, while others that underestimate or are too slow will their competitiveness in the market.

Literature review

A production system represents a model of a specified information processing system. They consist of a series of pieces, each containing certain conditions and actions. They also contain a set of data structures (expressions) that encode information about which production systems are running. [1] A production system can also be understood as the part of an organization or company, where inputs are transformed into outputs, i.e. where product offerings are implemented based on competitive priorities. [2] Agnovic [3] claims that a production system includes all structural processes, management systems and resources required for systematic product development, planning, production, i.e., most process within the value chain. Wu [4] pointed out that the production system consists of three genetic mechanisms necessary for the operation of the production systems:

- Physical infrastructure – hard elements of the production layout that describe the flow of materials within the system itself,
- Human and organizational structures – systems that take into account the interaction of employees in the production process,
- Employee roles and responsibilities – the information and control architecture allow for production and planning control.

It can be seen that support system constitutes the production process. Malindžák [5] defines a production process as "a system of transport, handling and storage operations involved in the production of a specific product during specific production stage".

Designing and simulation

In practice, when designing, we encounter different interpretations, of which there are many, because as always, there are multiple perspectives on a given topic. This is a very broad term, and the meaning of "project" can vary greatly across fields and from different perspectives. We encountered different interpretations, but the main idea is essential. In general, the design process represents a kind of conceptualization and design for the user itself. It actually represents the center of thinking, which brings the original idea. It's about creating solutions for a specific group of people, individuals, more abstract systems, i.e., anything we can think of. However, the output should always be to solve a problem or satisfy a need. It is more important to focus on primarily on the core of essence of the design itself, rather than what the design actually means. While the specific steps may vary across different fields or industries, in general, the design process includes the following steps:

1. Identification of problems,
2. Review the facts,
3. Define tasks,
4. Suggest solutions to problems,
5. Create models,
6. Testing and validation,
7. Evaluate and improve,
8. Implement. [6]

Authors Chung [7], Mourtizs et. al. [8] thing of simulation as an analysis, we need to get to overview of these complex systems, test new operational or capacity strategies and new concepts or systems before implementation but not least gather information and simulate the system now. It is considered an important helper from perspective of production logistics and the entire logistics process. Mainly because of their ability to coordinate processes, analyze and monitor production in detail, and plan and control production. [9] As such, they represent an integral part of today's processes. In practice, a large number of simulation systems are used, which are of different types or used in different industries.

Motivation for study

Recent expert studies predict that the global market for process control will grow to $14.4 billion by year 2025. The experts also noted a remarkable 73% increase in interest in business process management. Nevertheless, only 15% of companies are satisfied with the result. But what are these trends? Usage of RPA (Robotic Process Automation), AI (Artificial Intelligence), process mining, and low-code or no-code development to automate processes is highly trending due to the cut costs and boost efficiency in organizations. The paradigm of firms relying on low-code or no-code technologies will increase by 75% by 2024. It also shows us that more than 40% of businesses plan to replace current BPM (Business Process Management) tools to more intelligent software. Machine and deep learning will be used for predictive and perspective insights with collaboration with digital twin and IoT (Internet of Things). Traditional methodologies such as Six Sigma will be declining, while process intelligence and automation tools will continue to keep growing. Collaboration boosts productivity and customer satisfaction. BPM systems are expected to include real-time management. Companies are expected to shift toward real-time monitoring and implementation for agility to control capabilities for rapid changes and predictive process monitoring. Also, there is prediction of increase of automation data generation, leading to the rise of process analytic, which helps organizations to develop KPIs, make data-driven decisions and boost productivity. Customer-oriented process are essential for satisfaction. BPM measures customer effort, uses feedback, and maps customer journeys to enhance the experience. Sustainability is one of the most mentioned trends these days and it's still rising. Customers prefer environmentally friendly companies, that track and improve environmental metrics, compliance and sustainability goals. [10]

Fig.1 Top 10 BPM Trends of 2023 [10]

Human-robot collaboration (HRC) is a perfect example of a dream scenario for the future in workplaces. In the design of such collaboration, the main challenges are mainly in the distribution of tasks between robots and humans themselves based on their capabilities, the speed of their adaptation and the redesign of the workplace layout, but it is also about how the virtual implementation of the proposed production system ensures working conditions for the workers themselves. It has been proven that robots can adapt to these changes faster and easier especially when it comes to processes that change their character frequently, like humans. Manually controlled systems are also unable to respond to the new challenges of globalization and the ever-growing needs of mass consumption. The interactions between humans and robots in an industrial environment can be considered as a complex system. [11]

Discussion

Robotized workplaces generally represent a space, such as a production floor, where robots form a complex system. In general, robotized workplaces are standardized, i.e., the principles and structure are more or less the same, and usually the robots are in their own cell. However, a more precise specification depends on the type of production process, the operation and the premises themselves, as well as on the characteristics and features of the robot. [12] The creation of simulations of production chains based on robotic workstations is now standard in almost all large companies. It is logical that the design itself results from the nature of the production processes as well as from the production strategies, which also significantly influence the design process. [13] Virtual reality (VR) is a digital artistics environment that allows people to perceive and experience situations and events with their senses as in reality. Some experts believe that creating knowledge about a new technology in the early stages of diffusion can act as a catalyst for rapid adoption by increasing the likelihood of success. VR allows engineers, technologists, designers, and many other professionals, as well as non-interested parties, to try out the system in an intuitive virtual environment even before the initial capital needs to be invested, which also reduce the likelihood of error. There are studies that show us that a systematic HRC system design process that combines simulation and VR with digital twin is very necessary and valuable. [11] It is a simple, visual and powerful environment to design new production solutions using simulation software in 3D models. Mostly it is used in the automotive industry, electronics, pharmaceutical industry, heavy engineering industry, but also in packaging and palletizing, storage, but also within intralogistics and industrial engineering as such. [14]

Process of simulation and VR

The user first starts with the simulation design itself. By improving various data from CAD programs, a 3D model can be created. Also, the fact that software developers have included pre-simulated models in the program can be a great help that can facilitate the design process. This is followed by the actual modeling and programming, where the flow of the process is visually defined with easy-to-use tools. It is also possible to program the robots themselves using quick-learning tools. Only then can the user start the layout of the simulations and thus monitor the behavior of the simulated system, mainly monitoring the behavior of the processes and entities in the model itself. Thank to the ability to make quick changes to the designs and models themselves, the user can quickly correct an error in the simulation and then retest until they find the optimal configuration. The biggest advantage is the sharing of the obtained results in widely available formats with literally anyone. [15]

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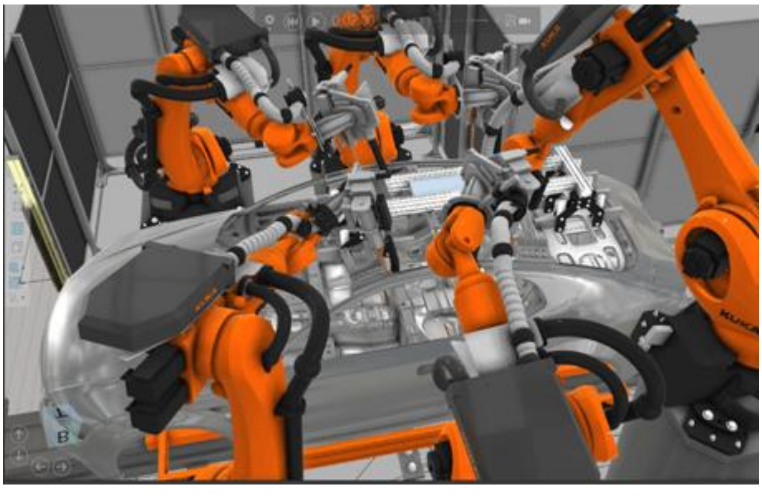

Fig. 2 VR simulation

Conclusion

Virtual reality and robotic workstation can definitely be considered as an important technology that could and should be used in the industry in all different environments. By using VR, all kinds of errors and collisions can be avoided, and what is most important is the fact that there is no need for large investments and there is no high safety risk for anyone while shortening time, reducing costs and thus providing the most efficient solutions. As mentioned earlier, the latest trends such as IIoT, digital twin or AI could help to remain competitive in 2023 and beyond. However, companies can prevent the negative and undesirable effects of crisis events by adopting new technologies, continuously innovating, shifting to data-driven processes, and moving to flexible operating models.

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ANALYSIS OF TECHNOLOGICAL PARAMETERS OF ADDITIVE MATERIALS FOR BIOMEDICAL ENGINEERING

Marianna TREBUŇOVÁ– Darina BAČENKOVÁ – Jana Demeterová

Abstract: One of the main tasks of biomedical engineering is the analysis of an innovative biocompatible material created by additive technology and incorporated with stem cells. In an *in vitro* environment, it is necessary to comprehensively analyze the suitability of the biomaterial for bioengineering, its therapeutic use, and at the same time verify and assess the suitability of the material as a matrix for stem cells. As part of the evaluation process, it is necessary to evaluate the mechanical properties, the degree of degradation and biocompatibility of the material, and to monitor the adhesion of cells to the material for successful cell proliferation *in vitro*. The resulting biomaterials that pass testing are therefore suitable for the creation of 3D matrices and usable for the formation of biomedical artificial tissues.
Keywords: biomedical engineering, biomaterial, biocompatibility, scaffold, stem cells

Introduction

The development and subsequent optimization of medically usable material is a complex process. A biomaterial can be defined as any substance, whether of natural or synthetic origin, that can be used as a system or only as a part of a given system, which has the task of healing and replacing a tissue, an organ, or even a function of the body. Advanced additive manufacturing enables the creation of sophisticated design and production of material with precisely specified properties. The material acting in the organism during the rebuilding process is subject to gradual degradation and the result is by-products that need to be non-toxic. Scaffold bioprinting is a process with a precise result, where the structure of the scaffold is precisely defined and printed with nanometer precision. As a result, it is possible to modulate the manner and rate of scaffold degradation by combining two or more materials with different time sequences of degradation (Fig.1).

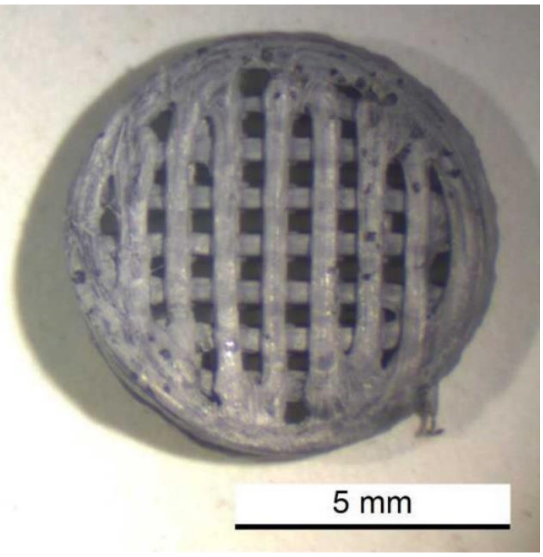

Fig. 1 An example of scaffold made of polylactic acid (PLA)/ polyhydroxybutyrate (PHB) blend for *in vitro* tests created by additive technology

The hydrophilicity of the scaffold surface actively affects the ability of the solution to flow through the scaffold, thereby directly influencing the kinetics of degradation. The rate and manner of degradation is influenced by the dimensions of the matrix and the ability of water to penetrate. If the solution molecules penetrate the 3-dimensional scaffold at a higher rate, this results in uniform and overall degradation. On the contrary, if the penetration of the solution is slow, the degradation manifests itself mainly on the surface of the material. The internal matrix remains largely unchanged. However, the methods of degradation do not depend only on external conditions but are further influenced by the type of material used. With each application, it is necessary that the relevant biomaterial ensures a sufficiently long-term use without the host's organism rejecting it. Of course, it must not lose its intended function either when presented with body environment. In order to achieve successful cooperation of the material and the host, not only the selection of biomaterials itself, but also the design must be considered. In addition to the fact that it is important for biomaterials to be sufficiently strong and flexible, one should not forget the other requirements for the composition of biomaterials that are placed in the human body. This includes biofunctionality, biocompatibility, biotolerance, corrosion resistance and others [1]. The rate of degradation of tissue constructions should reflect the rate of formation of new tissues. However, it should not exceed the speed of the given creation. It can be affected by many cellular processes, including tissue regeneration, cell growth, and host´s tissue response[2][3]. The most important measure of the properties of a polymer is the determination of the time during which the polymer retains its designed functions under the conditions of use. If the polymer is used in a biodegradable environment, the time it takes for the materials to fully decompose and lose mass is also important. From the functional time to the elimination time, the material loses its functionality, but still releases degradation products. Depending on the chemical and physical properties and release rate, degradation products may cause biocompatibility concerns. For a polymer to be used successfully, the activity/elimination time, and degradation products must be well characterized and controlled. To achieve this, we need to understand the mechanisms of its degradation [4]. During *in vitro* tests, the material is exposed to the effect of aqueous solutions that simulate the inorganic parts of blood plasma in the absence or presence of cell cultures. At the same time, the interaction between the solution and the surface of the material is investigated. Subsequently, crushed, and compact samples are tested for changes in the concentration of individual components. Attention is also drawn to the structural changes of the surface of the examined samples [5]. *In vitro* biodegradation is an imitation of real-time events that occur after the implant is applied. When testing the biodegradation of polymeric biomaterials, the European standard ISO 10993-13 is a suitable model. It involves immersing the biomaterial in solutions whose temperature is approximately 37°C during the long-term exposure period. Due to the influence of time and conditions, degradation of the biomaterial sample occurs. The obtained information is subsequently analyzed using molecular and mass balance. The *in vitro* tests of the material can partially replace experiments using laboratory animals. This can reduce the overall cost of testing. Repeated assessments in variable conditions with different parameters are possible. For *in vitro* testing, the ideal cell type is chorionic mesenchymal stem cells (CMSCs). Isolation of CMSCs from fetal membranes has several advantages. The tissue is obtained after birth, only after its physiological function had ended. Therefore it is a source of cells that can be used without ethical reservations. The advantage of the use of cells is their high proliferation potential and a precisely defined phenotypic characteristic [6]. The task of biomedical engineering is a preparation of scaffolds from selected polymer materials, which are potentially suitable for use in implantology and regenerative medicine. The benefit of determining *in vitro* degradation is a closer characterization of the investigated polymeric materials, which is key information for their further potential use (Fig. 2).

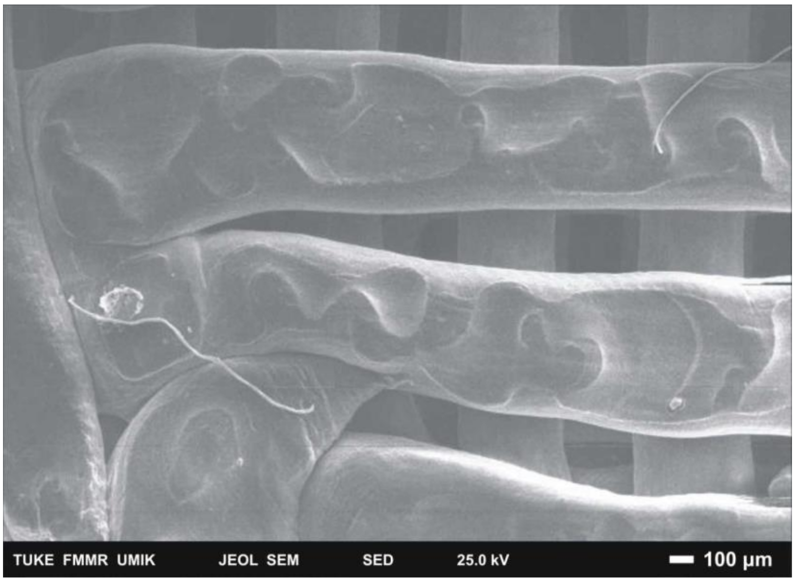

Fig. 2 Scaffold sample with visible cells evaluated via scanning electron microscopy

Using *in vitro* degradation determinates the influence of materials on the pH levels of the environment, absorbability of solutions by samples, and loss of weight of samples due to material degradation. The degree of degradation of the material and the change in its morphological and chemical properties can also be evaluated. By combining a scaffold with tested biocompatibility, cytotoxicity and autologous or allogeneic cells, biologically active, additive materials designed for tissue engineering can be created. Scaffolds created in this way are suitable for cell adhesion, proliferation, and the results lead to restoration and repair of the original tissue structure. The use of artificial tissue is possible for the therapy of defects in orthopedics and surgery, as functional substitutes for defects of hard and soft tissues, as well as for testing the toxicity and effectiveness of new drugs whose task is to imitate the environment of the human organism.

Conclusion

3D printing has seen very significant advances in recent times. Thanks to this technology, it will be possible to print scaffolds with great precision. Scaffolds seeded with cells will be able to be used for further research and drug testing. The subject of research are also new materials, their properties and specific use. Scaffolds loaded with cells will be mainly aimed at replacing damaged or non-functional parts of the human body. In tissue engineering and regenerative medicine, there is an increasing approach to the search for materials that would be suitable for implantation and would not require secondary intervention to remove them. Therefore, materials are being developed that degrade after implantation while new tissue is being created. It is therefore important to know the degradation properties of such a material in an environment similar to the human body.

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GLOBAL TRENDS IN 3D PRINTING

Ján KOPEC – Miriam PEKARČÍKOVÁ – Marek MIZERÁK – Waldemar WOZNIAK

Abstract: This article discusses new materials in the context of 3D printing technology and their practical applications in real life. With the growing interest in 3D printing and the continuous development of materials, new opportunities for innovation are opening in a variety of sectors, including industry, medicine, architecture, and consumer product manufacturing. This article focuses on an overview of the latest technological advances in 3D printing and identifies the key advantages of new materials such as biodegradable polymers, metal alloys, and composite materials. The article includes examples of specific projects and applications where new materials in 3D printing are delivering real value. Overall, the article highlights the importance of 3D printing and new materials as a tool for achieving technological innovation and improvements in a variety of fields and highlights the need for further research, education, and ethical reflection in their use.

Keywords: *3D print, FDM, 316L stainless steel, PLA, Filaflex*

Introduction

3D printing technology has become an indispensable tool for innovation and rapid prototyping in a wide range of industries over the past few years. One of the important factors that allows 3D printing to push its boundaries and deliver new possibilities is the new materials that are constantly being developed and improved. In this article, we will discuss one of the most widely used 3D printing methods, namely Fused Deposition Modeling (FDM) technology, and the new materials that accompany it.
FDM 3D printing, based on the process of melting and layering thermoplastic materials, has become a popular choice due to its affordability, speed, and ability to create both functional prototypes and end products. However, with the growing demand for personalized solutions and materials with specific properties, material manufacturers are focusing on developing new formulations that would provide even greater flexibility and precision in printing.

The flow of 3D printing varies depending on the printing technology used, but in basic terms, we can distinguish a few common steps. Here is the general flow of 3D printing:

- Creating a 3D model: The first step in 3D printing is to create a 3D model of the object you want to print. This model can be created in special 3D modeling software or by scanning an existing object.
- Model preparation: The 3D model needs to be processed using print preparation software (often called a slicer), which breaks down the 3D model into layers and determines how the object will be printed. The slicer also generates instructions for the printer on how to print each layer.
- Material selection: This step depends on the technology used. Different printers use different materials such as plastic filaments, metal powders, ceramic materials, etc. The material is loaded into the printer in the form of filament, powder or liquid, depending on the technology.
- Printing: The actual printing process begins. The printer sequentially prints each layer of material based on the instructions generated by the slicer. These layers are

successively stacked on top of each other, with each layer adhering to the previous one. This can take anywhere from a few minutes to several hours or longer depending on the size and complexity of the object.

- Cooling and Solidification: After printing, some materials need to cool or solidify to become solid. This may involve exposing the object to cool air or some other solidification process.

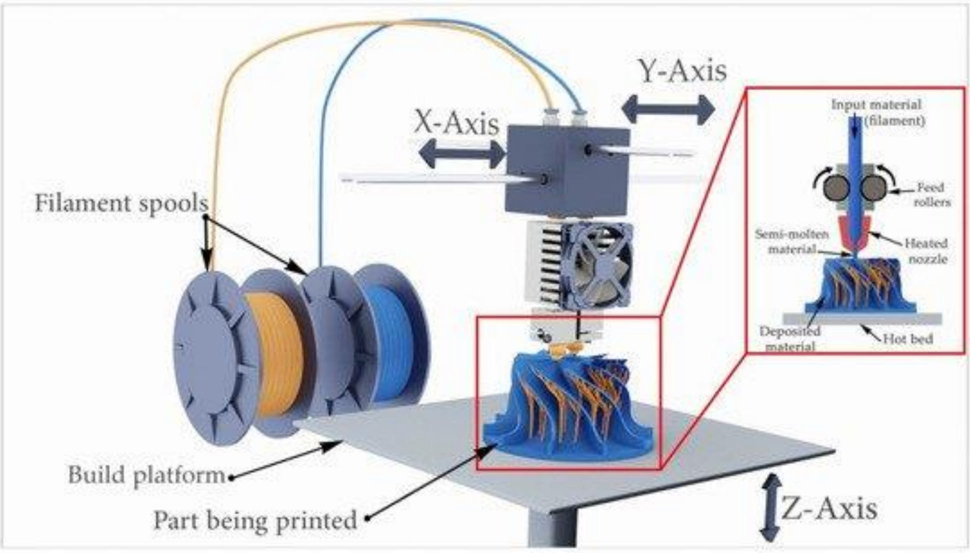

Fig. 1 The 3D printing process

1. Metalic filaments

The first group of progressive and new materials for 3D printing are metallic filaments. They have been available on the market for some time, and these filaments are usually a combination of a printing filament such as PLA and a small amount of metal powder. The combination of the two heterogeneous materials in the printing process yields favorable properties for the print. The metallic filament printout can be further processed (ground or polished) to achieve a metallic appearance. There are metallic polymers on the market with different metallic particle ratios. Filament manufacturer The Virtual Foundry, however, has shifted the ratio to a new line where they offer a filament with a high metal powder content. The parts are so metallic that they can be further processed by operations such as sintering, achieving fully metallic parts through FDM 3D printing, which was previously unimaginable (Fig.1). Manufacturer The Virtual Foundry offers filament with a high copper content (up to 90%). A conventional FDM printer can handle this material, it is just necessary to use a string heater through which the filament is introduced to eliminate curvature and minimize friction in the extruder and HotEnd. The sintering process can be done in a protective vacuum environment or in an internal environment. The extrusion that undergoes the sintering process is fully metallic with true metal properties such as electrical conductivity, and the ability to polish grind, or further weld the extrusion.

The extrusion has significant drawbacks compared to conventional copper components, such as a certain degree of porosity and volume reduction due to the removal of the polymer (PLA).

Fig. 1 3D model of a ship made of unfired copper, after descaling and sintering [source: The Virtual Foundry]

2. 316L stainless steel

316L stainless steel is composed of chromium-nickel-molybdenum. It is an austenitic stainless steel with low carbon content (Fig.2). In the annealed state, it has the properties of an antimagnetic metal and hardening is not possible, but it has favorable forming properties and gains durability by deformation. The disadvantage of this filament is that its stiffness is at a high level and more forming effort is required. Due to its good ductility, tensile strength, heat resistance, and corrosion resistance even at high temperatures, it is used across industries (paper, textile, chemical, and pharmaceutical industries), due to the barrier of contamination from metals.

The Virtual Foundry has been the pioneer in developing metallic filaments for 3D printing after many years of research and development. The great competitive advantage developed is that to obtain the pure metal parts it is only necessary to print the piece and sinter it in an oven. Other manufacturers that have tried to develop metallic filaments need to do one more process (prior to sintering in the furnace) which is the debinding that consists of a chemical process to separate the binder polymers from the metal.

Due to the high metal content (more than 80%), it is also necessary to use a heater in the FDM printing process.

Fig. 2 Gear made of 316L stainless steel without sintering and Model manufactured with Filamet™ 316L stainless steel and sintered [source: The Virtual Foundry]

3. Conductive flexible filaments

Some PLA-based fibers with conductive properties, such as Proto-Pasta's PLA fiber, are available at the thru. Recreus has launched a new material called Filaflex Conductive.
Filaflex Conductive is one of the filaments from manufacturer Recreus, which has developed Filaflex 82A, Filaflex 70A, or Filaflex 60A Pro, which are the most flexible and elastic materials on the market for 3D printing.
Filaflex Conductive is a flexible and elastic TPU-based filament. With a hardness of 92A, it achieves 100% elongation when stretched. When tensile forces are released, it returns to its original state without deformation or filament distortion. It represents a very easy-to-print material, compatible with almost every FDM 3D printer, even Bowden extruder printers. However, its unique property is electrical conductivity (Fig.3).
The conductive filament has a bulk resistivity of approximately 3.9 Ω-cm, which is more than conventional conductive filament. The bulk resistivity of a filament represents a measure of the material's resistance to electrical energy within one cubic centimeter of material. Resistance is principally affected by printing.
The main application areas of Filaflex conductive fiber are used as flexible conductive traces and electrodes (interconnection of computers, Arduino components, LED power supply, digital keyboards, pressure sensitive buttons, medical devices, electrodes for electrocardiogram) and electromagnetic and radio frequency shielding (telecommunication technology, hospital equipment, aerospace, and automotive components, shock-resistant cushioning.

Fig. 3 Filaflex conductive fibre extrusion [source: Recreus]

4. Compostable fibers with specific properties

The development of printing filaments has come a long way since its inception to create a filament with a high degree of sustainability and less impact on the environment.
Until now, the least harmful filament in FDM 3D printing has been PLA material, which is a biodegradable natural fiber polymer made from starch derived from corn or sugar beets. However, it has its disadvantages, and the most significant disadvantage is the low softening temperature.
For this reason, a fiber has been developed by Fillamentum called NonOilen, this filament is characterized by good mechanical properties, like PE, PP, or nylon filament. It is also suitable as a material because it is non-hazardous and non-contaminating to foodstuffs and is dishwasher safe.

The filament is made from fibers from oysters (Fig. 4), mussels, wheat, coffee, hemp, or beer. All these fibers offer an alternative to other petroleum-derived materials, creating a lower environmental impact. In addition, they are committed to a circular economy and use local raw materials to produce their filaments.

Fig. 4 Filament and part printed with PLA Oyster [source: Francofil]

5. Special trends in the use of 3D printing from around the world

A company in the footwear industry created the Parametriks 001 sneaker (Fig. 5), which is comfortable, stylish, and easy to make. Like crocks, only one material is used in the creation of the sneaker, which is injected into the form of the shoe. The model is created using parametric algorithms. The shoe has a design of a connected triangular mesh matrix that hugs a person's foot and fits great as it is custom-made. The material used for such a shoe is made of TPU filament. Sure, the holes on the sole of the shoe open you up to pebbles, thorns, and water, but on the other hand, this piece of footwear is purely experimental as it hopes to explore what a parametric piece of footwear can look like.

Fig. 5 Shoe made of flexible TPU filament

Aptly named The Throne, the sustainable toilet is designed to compost solid waste while solving the sanitation crisis. This solution eliminates plastic waste, using it as a building material, without burdening landfills. This toilet (Fig. 6) is created on a 7-axis 3D printer and is being tested in a habitat in the Swiss Alps. The Throne consists of 3 parts (a teardrop-shaped body, a sliding door, and a solid waste container). Everything was created in just 3 days, including the base and minor accessories.

Fig. 6 The Throne Sustainable Toilet

Conclusion

This article focuses on 3D printing technology the use of new materials and how to incorporate them into real life. In conclusion, 3D printing technology opens new possibilities for innovation and improvement in many aspects of our daily lives. New materials and their use in this field have the potential to change various sectors, including medicine, industry, and architecture. It is important to continue research and development in this area so that we can take full advantage of all the benefits that 3D printing, and new materials bring. With increasing understanding and creativity, we will be able to create even more amazing and effective solutions that will help us improve our world. People should have access to information and education about these technologies so that they can better understand their potential and contribute to their development. In addition, we need to pay attention to the ethical and environmental issues associated with 3D printing and new materials. As the use of these technologies increases, it is important to ensure that they are used responsibly and sustainably.

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DESIGN INNOVATION TO INCREASE THE COMPETITIVENESS OF COMPANIES

Renáta Ševčíková – Dagmar Klepochová

Abstract: The role of design in product innovation has been increasing recently. As a result of easier access to the same technologies, with firms increasingly competing with each other on price and product functionality, design has emerged as a key element bringing differentiation and competitive advantage. The strategic role of design-driven innovation is increasingly recognized. In this paper, we examine the attitude of Slovak firms from different industrial sectors towards innovation as a source of competitive advantage. It focuses on exploring the role design plays in firms and we investigate the interdependence of these two variables. Slovak firms recognize product innovation as an important source of competitive advantage, and at the same time a statistically significant dependence of this attitude with the role design plays in the firm is confirmed.

Keywords: Design Innovation, Competitiveness, The Role of Design.

Introduction

The importance of innovation for corporate competitiveness is now widely recognized and the strategic role of design-driven innovation is increasingly acknowledged. Many researchers present empirical evidence supporting the thesis that design, or more precisely design investments, positively influence the innovative capacity of companies [1, 2, 3].

There is a consensus within the countries of the European Union that all forms of innovation need to be supported in order to ensure competitiveness, prosperity, and well-being. Design is currently seen as a key discipline and activity that brings ideas to market and transforms them into user-friendly products or services [4].

The European Design Innovation Initiative was launched in 2011 with the aim of fully exploiting the potential of design-led innovation and linking design, innovation, and competitiveness [5].

To accelerate the uptake of design in innovation policy, three strategic areas for action are of particular importance:

- Promoting understanding of the impact of design on innovation.
- Promoting design-based innovation in industrial sectors for Europe's overall competitiveness.
- Promoting the uptake of design to support recovery in the public sector.

Marketing scholars and practitioners focus on aspects of innovative design that enhance consumer preferences and evaluations and provide a competitive advantage. Consumers prefer innovative to generic designs, and many companies are focusing on design-based innovation.

Product design innovation is becoming a strong foundation for companies to compete in global markets. Design thinking helps companies see new opportunities for innovation that are driven by a deep understanding of people's needs. These innovations start with the primary goal of creating offerings that are desirable to users and meet their needs, thereby creating value for the user. Creating offers with higher user value in turn increases the economic and business value of offers [6].

The relationship between design and innovation can be found in many publications. Research has identified three main ways in which design is related to innovation.
(1) It provides a symbolic representation as a vision for innovation, which is closely related to design's ability to visualize ideas.
(2) It creates greater meaning for innovative products and services, which brings.
(3) It conditions the way the company as a whole creates and sustains the innovation itself in terms of operational and strategic management.
An important component of all the above links between design and innovation is the ability of design to manipulate and visualize creativity to solve complex problems at different levels of the organization [7].

Methodology
The object of the research were Slovak companies with predominant activity in various sectors of industrial production.
The online survey was conducted between July and September 2021, when we distributed the questionnaire to selected firms. The survey sample was supplemented with the results of the face-to-face data collection, which took place in the period October-November 2021. After data cleaning, we worked with a sample of 239 firms from different areas of industrial production.
The aim of the survey was to determine the attitude in firms operating in the Slovak Republic in selected industrial sectors at the high, medium, and low technology level towards innovation, towards the use of design in product innovation and to determine the level of skills attained in particular areas of design management. Some partial results are presented within this paper.
Analytical and statistical methods were used to evaluate the results of our survey and to analyze the data. We examined the relationships between variables using correlation coefficients, which were tested for statistical significance of the model. Due to the nature of our surveyed data, we used a correlation coefficient - Cramer's V. The Cramer's V statistic assesses the association between two nominal variables or between nominal variables and ordinal variables with multiple categories. Cramer's V ranges between 0 and 1 without any negative values. A value close to 0 indicates no association. However, a value greater than 0.25 is indicated as a very strong relationship for Cramer's V [8].

Cramer's V is calculated when the square root of the Chi-square statistic is divided by the sample size and the minimum dimension minus 1.

$$V = \sqrt{\frac{\chi^2/n}{\min\,(c-1, r-1)}}$$

The $\chi 2$ = is derived from Pearson's Chi-square.
n = total number of observations; c = total number of columns; r = total number of rows.

Results
Almost 85% of our research sample (202 firms) consider innovation to be an important source of competitiveness and only 37 firms, representing 15% of our sample, do not share this view.
The role of design in the firm is based on the concept of G. Kootstra [9] and defines the use of design within 4 stages:
1. Design plays an important role in the firm's strategy; it is part of the firm's culture.
2. Design is part of the process of innovation and development of new products or services.
3. Design is used to a limited extent, only as an enhancement to the appearance of products, packaging, overall style.

4. Design is not used in the company.

Our survey shows that more than 67% of firms that do not consider innovation as an important source of competitiveness report that design is not used at all in the firm. For firms that consider innovation as an important source of their competitiveness, only 16.8% of them do not use design at all. In 83.2% of firms in this category, design is used in some way, whether it plays an important role in the firm's strategy (26.2%), is part of the process of innovation and new product development (31.7%), or is used to a limited extent, only as an improvement in the appearance of products (25.2%). Using Cramer's V statistic, we confirmed a statistically significant strong correlation between respondents' positive attitudes towards the perception of innovation as a source of competitive advantage and the role of design in the firm (Figure 1).

Symmetric Measures

		Value	Approximate Significance
Nominal by Nominal	Phi	,435	<,001
	Cramer's V	,435	<,001
N of Valid Cases		239	

Fig. 1 Distribution of responses

We can conclude that the more important the role of design in the firm, the more the firm perceives design innovations as a significant source of competitive advantage.
In addition to achieving a competitive advantage, respondents also mentioned other benefits of using design in product innovation - improved brand/product image and reputation, increased sales volume of the company's products, higher market share and success in foreign markets.

Conclusion

The contribution investigated the attitude of Slovak companies from various branches of industrial production to the use of design in product innovations and the study of their advantages. Slovak companies perceive design innovations as a strong source of competitive advantage. However, this attitude is very strongly related to the role that design plays in the company and its strategy. A statistically significant positive dependence was confirmed between these variables. At the same time, companies perceive other advantages of product innovations based on design, namely - improvement of the image and reputation of the brand/product, increase in the sales volume of the company's products, higher market share and success in foreign markets.
Understanding the benefits of using design in product innovations can help support the innovative activity of companies and thereby increase their competitiveness.

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TRANSFORMING INDUSTRIES THROUGH TALENT MANAGEMENT: EXPLORING VR/AR IN LEARNING AND DEVELOPMENT OF INDUSTRIAL ENTERPRISES IN THE ERA OF INDUSTRY 4.0

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Abstract: One of the challenges of Human Resources Management (HRM) in terms of ensuring sustainable development is Talent management. From a HRM perspective, digital transformation suggests attracting employees who have both digital and soft skills. One of the key challenges for today's employers is competing for talent with these skills. The main research aim was to examine the linkage between talent management, primarily in the field of learning and development in industrial companies, and the new technologies introduced by Industry 4.0 in Slovakia. The research focuses on experiences with artificial intelligence (AI), virtual and augmented reality (VR/AR), in the education domain within the framework of talent management processes in in medium-sized and large enterprises. The survey was designed to gain answers and knowledge that emerged from the research. The survey was conducted online, and Microsoft Excel was used for survey data processing. From the responses gathered through the survey, it is evident that there is a direct correlation between the continuous arrival of changes, the emphasis on research and development, and the introduction of new innovative technologies. These developments have also extended their influence into human resource management, directing attention of industrial enterprises towards talented employees and their learning and development via innovative technologies.

Keywords: Augmented Reality, Human Resources, Industry 4.0, Talent management, Virtual Reality

Introduction

Numerous technologies such as robotics, artificial intelligence, and additive manufacturing contribute to product and process innovations that will make everything smart and connected (e.g. the smart factory) [1]. However, organizations need to realise that although new technologies are the driving force of the fourth industrial revolution, high market share or the production of high quality products will not be fulfilled by new innovative technology alone, but ultimately, it is the human resources that integrate these technologies into the various processes in organizations. Human resources (HR) are valued for their skills, efficiency, creativity and development abilities [2],[3]. Thus, effective management of human resources is crucial to successful business management, and this requires a strong emphasis on their management throughout the entire employee lifecycle [4],[5].
Organizations in the 21st century face crucial challenges **concerning** human capital. One of these challenges is talent management. Each organization may interpret the concept of talent differently, because each organization has different demands, requirements, and expectations and operates in different terms, with different focuses and needs. In general, however, talent is perceived as a combination of different abilities, skills, qualities, and qualifications, enriched

by the potential for their possible further development. In summary, talent is a combination of various skills, capabilities, traits, and credentials, which can be enhanced through continuous growth and progress. According to [6],[7],[8] talent management can be understood as a set of activities and processes to ensure that an organization seeks, retains, and develops employees who are characterized by specific skills, qualifications, and experience. The effective management of talent is heavily influenced by the institutional and cultural context of each organization, in addition to the integration of standardized practices such as laws and institutional norms. This crucial process empowers organizations to enhance their competitiveness and thrive in their respective industries [9]. The talent management strategy should match the goals of the organizations and clearly define what type of talent the business needs [10]. Creating an effective talent management strategy is a long-term and complex process. There are basic steps that will help an organization [11]:

- alignment with strategic priorities,
- linking with talent management practices,
- defining the necessary HR processes,
- analysing, regularly adjusting and planning for the future.

Regardless of best practices, organizational fit is paramount in a talent management strategy: alignment with strategic goals, with corporate culture, with other HR practices and policies, and with organizational capacity. [9]
Talent management also aims to stimulate creativity [12]. Organizations rely on the creativity of their employees, so managers should strive to stimulate the creative potential of their employees [13] and create a work environment that emphasizes continuous learning [14]. Talent development is an area that must be continuously addressed by the organization. Talent training currently focuses mainly on such individual qualities as the ability to analyse data, the ability to continuously self-improve, communication and entrepreneurial skills, creativity, the ability to anticipate situations, etc. [15]. Through systematic learning, an organization will secure highly qualified talents who will be able to apply theoretical and professional knowledge[16],[17]. .

Methodology

After laying the theoretical groundwork for understanding the interplay between Talent Management, Learning and Development, and Industry 4.0, this chapter shifts its focus to assessing how these ideas are currently being put into practice. Specifically examines their applications in managing industrial enterprises in Slovakia. The main research aim is to examine the linkage between talent management, primarily in the field of learning and development in industrial companies, and the new technologies introduced by Industry 4.0 in Slovakia. The research focuses on experiences with artificial intelligence, VR, and AR in the education domain within the framework of talent management processes in in medium-sized and large enterprises.
The survey was conducted between March 17, 2023, and June 6, 2023. It was distributed exclusively in electronic format to respondents contacted through LinkedIn. The research sample included HR department employees from medium and large enterprises, as the survey required a deep understanding of Talent Management processes and future HR goals. Small industrial enterprises were excluded due to limited Talent Management development in such contexts. Microsoft Excel was used for survey data processing. 396 respondents representing

medium and large Slovakian industrial enterprises were approached, yielding 134 completed survey responses. After careful processing, 121 complete surveys were retained for analysis. To fulfil the main research aim we have determined four questions in the survey for a specific research sample to set out to frame and address the aim of the research.

The survey questions were formulated as follows:
Q1: *Which elements of Industry 4.0 do you have implemented in your organization?*
Q2: *Which competences are considered to be the key competencies that a talented employee should have?*
Q 3: *How do you retain talented employees?*
Q4: *What types of new technologies do organizations use for the learning and development of their employees?*

To answer the survey questions, the authors of the paper used the tools of descriptive statistics.

Research

Q1: *Which elements of Industry 4.0 do you have implemented in your organization?*

The first question is focused on Industry 4.0 The outcomes are presented in Figure 1.

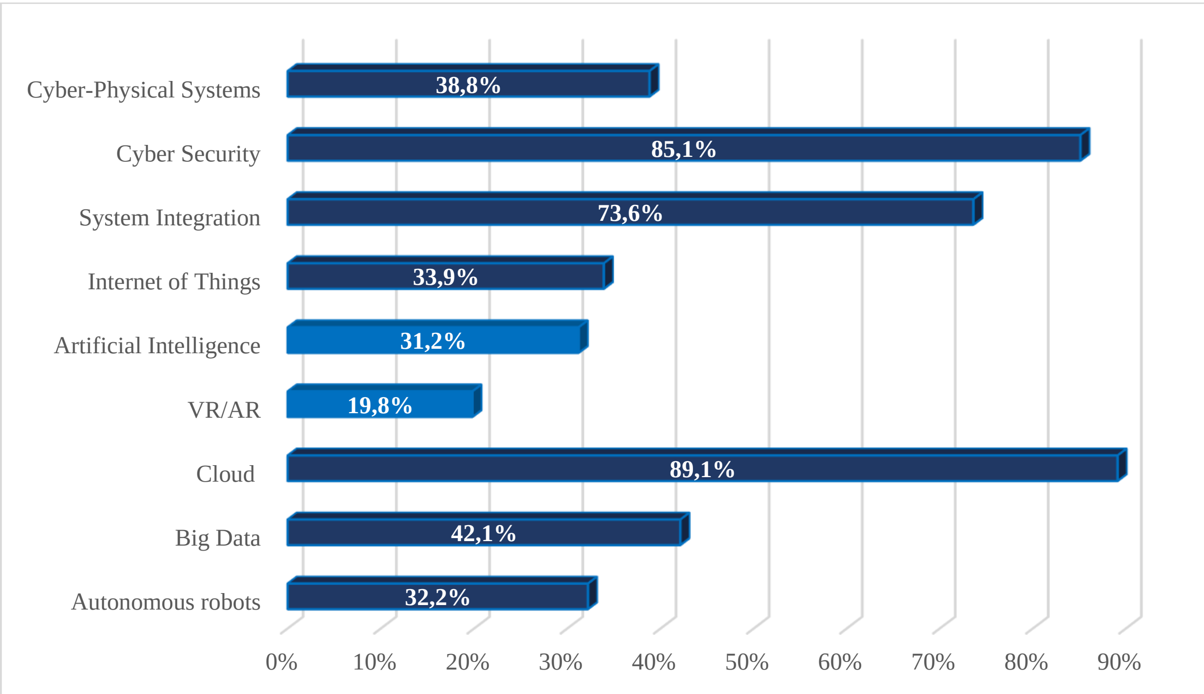

Fig. 1 Elements of Industry 4.0

As is evident, the majority of respondents detect the presence of Cloud solutions (89,1%), Cyber Security (85,1%), and System Integrations (73,6%) within their respective enterprises. Additionally, emerging elements like Artificial intelligence (31,2%), Virtual Reality, and

Augmented Reality (19,8%) are also starting to appear, which have been largely absent from the Slovak market in recent years.

Q2: *Which competences are considered to be the key competencies that a talented employee should have?*

The second research question focused on which competencies respondents believe employees who are considered talented should possess. The results are shown in Figure 2.

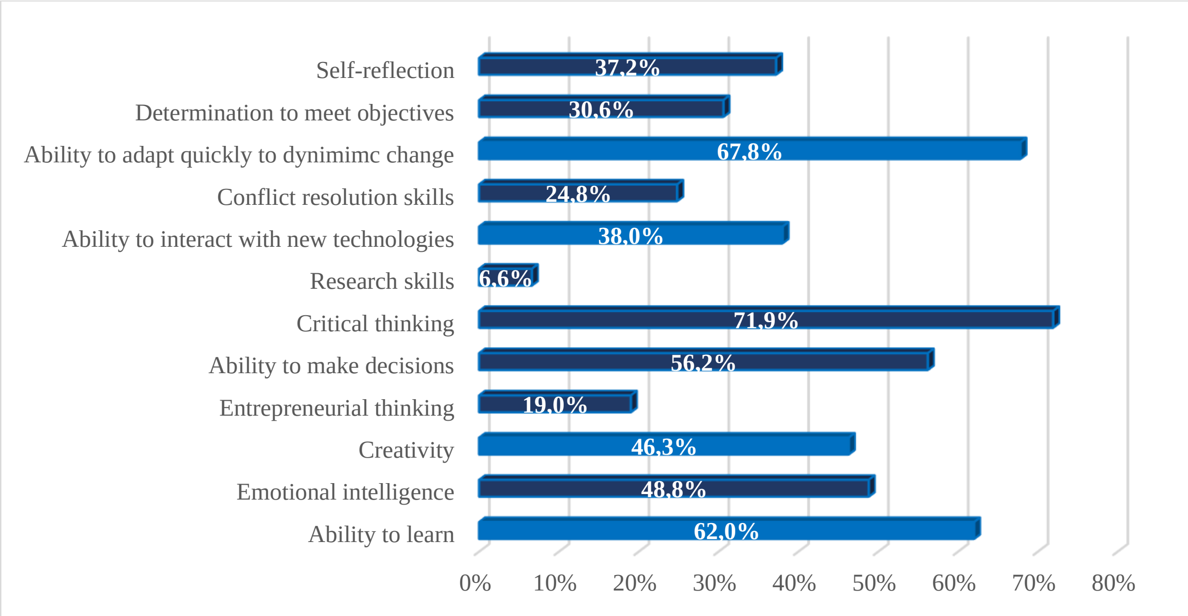

Fig.2: Key competencies of talented employees

The responses in Fig.2 reveal that abilities such as Ability to adapt quickly to dynamic change, Ability to learn, Creativity and Ability to interact with new technologies - directly influenced by Industry 4.0—are gaining prominence. In an era marked by unceasing change, innovation, and technological progress, enterprises are no longer merely seeking leaders capable of management. The competitive edge now hinges on adeptly embracing continuous change, resourcefully devising solutions, and effectively integrating novel technologies.

Q 3: *How do you retain talented employees?*

Presently, enterprises are grappling with the pursuit of exceptional, talented employees. In light of this, we turned our attention to the issue of talent retention within the company. The subsequent question aimed to uncover strategies for retaining talented employees. A notable 42.2% of enterprises deem the most effective approach to retaining talented employees to involve a tailored system of employee learning and development. This system allows employees to not only select their training but also choose their educational paths, often involving modern technologies such as artificial intelligence and VR/AR. Meanwhile, 31.2% of enterprises entrust their employees with specialized tasks centered around innovation and technological advancement. These tasks are executed using state-of-the-art technologies. Corporate culture, along with distinct remuneration and compensation strategies, ranks third at 11%.

Q4: *What types of new technologies do organizations use for the learning and development of their employees?*

However, competency requirements may change due to technological progress and development. It is becoming a non-negligible phenomenon that new technological elements also affect the field of employee education. Thus, the last question is focused on what types of new technologies do organizations currently use for employee learning and development.

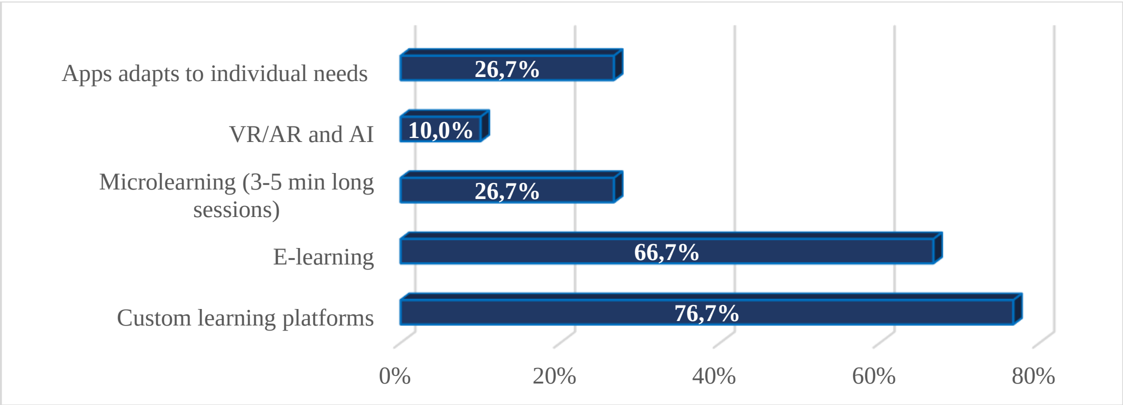

Fig.3: Technologies used for employee learning and development

In the responses shown in Figure 3 we can see that enterprises still prefer Custom learning platforms (37%) and E-learning (32%). Only 5% of them use AI or VR/AR for Learning and development of their talented employees.
As a final question of survey, we asked respondents: *"Which element of Industry 4.0 could better contribute to the learning and development of your employees?"* To exclusively highlight the most recent technologies prevalent in the Slovak market, we limited respondents to just two options for selection: VR/AR or AI. The responses showed a notable predominance of VR/AR (73.3%), potentially attributable to the robust presence of the automotive industry and widespread industrial production that relies on simulations for learning and development purposes.

Conclusion

The ability of creative thinking of employees in the current dynamic-changing environment is necessary. The strategy of talent management helps organizations to ensure that their effort and investments were not useless. It helps organizations prepare their employees who will ensure the organization's success in the future. Effective talent management ensures that valuable human potential is fully utilized.
From results of survey, we can see that in Slovakia new technologies in Learning and Development of employees is still in its early days. But the adoption of AI and VR/AR technologies in learning and development processes for industrial enterprises is imperative. As Industry 4.0 reshapes industries, nurturing talented employees becomes pivotal for success. While we observe the growing presence of AI and VR/AR, there is still a need for increased focus from HR departments. By integrating AI and VR/AR, these employees gain adaptive skills and hands-on experiences, bridging theory and practice effectively. This is particularly

crucial for Slovakia's automotive and manufacturing sectors, as VR/AR enhances skill development and AI offers data-driven insights. Embracing these technologies isn't just a choice; it's a necessity for staying competitive, fostering innovation, and securing long-term growth in an evolving global landscape.
Human Resources Management has without a doubt the best position in the organization considering the systematic view of its structure. It can ensure communication, coordination, and cooperation throughout the whole organization. HRM should emphasis on effective seeking of employees, targeted learning, and development, which in summary leads to organizational success[18]. Talent management requires management support, and also the integration of all processes, so only in this way it can become a driving force for performance improvement [7]. An emphasis on continuous talent learning and development is necessary. Organizations should focus on the use of new technologies, offered by the current era and which which will enhance the creative thinking of employees due to the easier ability of individuals to integrate learned knowledge into the real world environment[13]. Training programs in which are used new technologies have become a new learning and development trend in the 21st century. Organizational management should be able to create conditions for increasing the quality of the learning and development system and for learning services [19].

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THE IMPORTANCE OF GENDER EQUALITY IN THE WORKPLACE: A SURVEY RESEARCH IN SLOVAK INDUSTRIAL ENTERPRISES

Veronika JURENKOVÁ - Miloš ČAMBÁL - Peter SZABÓ

Abstract: This paper follows on from ongoing research in the field of gender equality with the aim of assessing the current state of gender equality in large industrial enterprises in Slovakia in the context of Industry 4.0. It is the fourth industrial revolution that brings with it opportunities for improving gender equality, which is the fifth of the goals of sustainable development of society within the 2030 Agenda, which calls on states to take a joint, coordinated approach to solving global challenges. Gender equality is a fundamental human right and forms the basis for a prosperous, sustainable world. The contribution will present the results of the questionnaire survey, through which we will gain knowledge about the current state of gender equality in the context of industry and identify potential areas for improvement. The questionnaire survey will be conducted online, and to ensure the validity of the obtained data, respondents holding managerial positions will be contacted. The results of the questionnaire survey will represent the current, slowly improving state of gender equality in industrial enterprises, while at the end we will present suggestions on how to advance the current situation in terms of Industry 4.0.
Keywords: gender equality, diversity, industrial enterprises, questionnaire

Introduction

Gender equality does not define the equality of men and women, but their equal social status, rights, duties, responsibilities, and fair access. Gender equality is a basic human right and forms the basis for a prosperous, sustainable world [1]. On the contrary, gender inequalities bring different forms of discrimination and injustice within the entire social structure [2].
The goal of gender equality is to create opportunities for both men and women to apply themselves while fully preserving their diversity. Increasing gender equality removes the hierarchy in the position of women and men in society [3]. Gender equality is also defined as the fifth goal of sustainable development in the framework of the 2030 Agenda, which calls on states to take joint coordinated action in solving global challenges. One of the measures to achieve this goal is the elimination of all forms of discrimination [4]. Achieving complete gender equality is not expected in the next century, as the causes of gender inequalities are rooted in society. Raising awareness of the issue and its economic benefits leads to a shift in thinking in the given area. The World Economic Forum predicts that gender equality in the workplace will not be balanced until at least 2095 [5].
If industrial enterprises want to achieve better results, they should realize that a gender-balanced workforce is a business advantage. Diversity brings more points of view, more knowledge, experience, interests and ideas [6]. The World Bank and the World Economic Forum have confirmed that women have enormous purchasing power. Regardless of what the business sells or services, it is very likely that women have a large, if not majority, influence on it. This is precisely why companies should realize that gender-balanced teams of male and female executives who decide on the company's direction are a great advantage nowadays [7]. The implementation of gender equality in the workplace is not just a formal task that the company ticks off as fulfilled. It is about providing equal opportunities and equal treatment to men and

women, which benefits business and company culture. The top management of companies often claim that they care about gender equality in the workplace, but actually, they do not implement any concrete steps to improve the current situation of gender equality. The year is 2023 and there are still many businesses that are dominated by one gender, the male [8].
Industry 4.0 also brings with it new possibilities for improving existing gender inequalities and eliminating stereotypes in the industrial field. This new era of technology and automation provides us with an opportunity to overcome longstanding gender gaps in the workplace. However, to really fulfill these positive prospects, it is essential to pay special attention to the promotion of gender equality and equal opportunities for both sexes. It is equally important that we realize that with new technological possibilities come new challenges. Industry 4.0 can lead to the creation of new jobs and industries, but it can also affect traditional job roles. It is necessary to ensure that these changes do not worsen existing inequality or injustice between the sexes. We must consciously and proactively try to minimize any potential negative consequences that new technologies could have on gender equality. Both sexes should have equal access to education, opportunities for career growth and decision-making positions. If we succeed in achieving these goals, Industry 4.0 can really move society towards a more inclusive and fair working environment for all [9], [10].

Methodology

The aim of the research was to analyze the current state of gender equality in large industrial enterprises in Slovakia in the context of Industry 4.0.
We set 3 research questions, which will need to be subsequently evaluated and interpreted.
RQ1: *What is the current state of gender equality and equal treatment of men and women in large industrial enterprises in Slovakia?*
RQ2: *What methods of education in the field of gender equality are used by large industrial enterprises in Slovakia?*
RQ3: *What obstacles do the employees of large industrial enterprises perceive in connection with the implementation of the gender equality policy?*
The data was obtained through an online questionnaire, which was distributed to respondents of large industrial enterprises through e-mail communication and the LinkedIn platform in the time horizon from 1.3. 2023 until 28.4. 2023. A total of 68 respondents filled out the questionnaire, it means 68 large industrial enterprises. From the authors' point of view, the sample of 68 is sufficient, as 1 respondent represents 1 large industrial enterprise and there are currently 292 large industrial enterprises in Slovakia in total. The questionnaire contained 15 questions, while the first two questions focused on the age and gender of the respondents. To ensure the validity of the obtained data, respondents holding managerial positions, primarily from the human resources department, were approached. The authors of the paper used MS Excel to evaluate the obtained data.

Tab. 8 Representation of respondents by gender

GENDER	WOMEN	MEN
	51%	49%

Table 1 shows the representation of respondents by gender. Of the total number of respondents, 51% are women and 49% are men.

Tab. 2 Representation of respondents by generation

GENERATION	Baby Boomers	X	Y	Z
YEAR OF BIRTH	1946-1964	1965-1980	1981-1995	1996-2012
%	4%	32%	52%	12%

Table 2 shows the representation of respondents divided by individual generation groups. Respondents could choose from the following answers: "Baby Boomers (1946-1964)", "Generation X (1965-1980)", "Generation Y (1981-1995)" and "Generation Z (1996-2012)". There were the most respondents of Generation Y, namely 52%, Generation X 32%, Generation Z 12%, and respondents belonging to the generation of Baby Boomers represented only 4%.

RQ1: *What is the current state of gender equality and equal treatment of men and women in large industrial enterprises in Slovakia?*
Based on the results of the questionnaire survey, the majority of men and women are familiar with the issue of gender equality, and even up to 94% of respondents consider gender equality to be important, which is a positive finding. The research also confirmed that the majority of large industrial enterprises in Slovakia have gender equality included in the vision of the industrial enterprise, and even up to 63% of respondents said that their current personnel strategy supports gender equality. Based on these answers, it can be concluded that a good basis for strengthening the current state of gender equality has been created in large industrial enterprises in Slovakia. But the fact remains that it is not enough to be familiar with the issue of gender equality and consider it important, but it is also necessary to constantly educate yourself in the given area and implement individual steps towards the improvement of gender equality.
Although the responses from the respondents prove that large industrial enterprises include gender equality in their long-term visions and personnel strategies, it can be concluded that an exclusive and specific plan that would focus on achieving concrete gender equality is still largely absent. Only a meager 6% of respondents declared that their company has a gender equality plan with the aim of actively engaging in its achievement. This more detailed analysis suggests that there is a possibility that the full implementation of true gender equality is still insufficient.
A positive finding from the respondents' answers is that the majority of both men and women stated that they do not feel different treatment from the point of view of gender equality and think that women and men have the same chances and opportunities for career growth. Even in these "sub-areas", however, there is room for improvement, as 29% of women out of the total number of women think that men are at an advantage and 46% of women think that men have better chances and opportunities for career growth.

RQ2: *What methods of education in the field of gender equality are used by large industrial enterprises in Slovakia?*
The evaluation of RQ2 is supported by the respondents' answers to the 8th and 9th questions from the questionnaire.
Question 8 was: "Does the industrial enterprise where you are employed provide gender equality training to male and female employees as appropriate?"

For this question, respondents were given a choice of the following answers: "Yes", "No" or "Don't know".

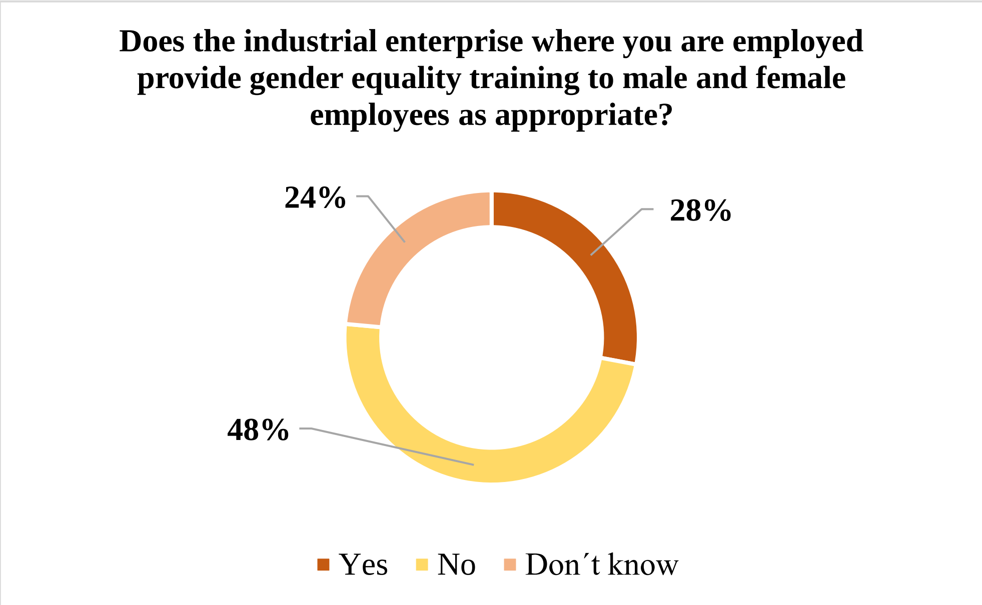

Fig. 1 Respondents' answers to question 8 of the questionnaire

Based on the answers of the respondents, which are shown in Fig. 1, we can conclude that gender equality education is insufficient in large industrial enterprises in Slovakia. As many as 48% of respondents stated that the industrial enterprises where they are employed do not provide them with training in this area, which means that employees often do not even know what positives improving gender equality brings with it.

28% of respondents said that companies provide them with gender equality training. They were given the opportunity to comment on which of the different training methods mentioned in the questionnaire are used in the company where they work.

The answer to the second research question RQ2 can be supported by the answers of the respondents who were asked in question 9 which of the above-mentioned methods of training they use in the industrial enterprise in which they work.

Question 9 was: "If you answered "Yes" in the previous question, which of the above training methods are used in the industrial enterprise in which you are employed?"

For this question, respondents were also given the option to indicate more than one of the following answers:

- gender awareness training as an important tool to raise general interest in gender equality issues,
- special training courses for persons who apply gender mainstreaming in the industrial enterprise where you are employed,
- expertise on the state of gender equality, where gender equality specialists help individuals to 'translate' what they have learned into practice and check that the objectives set are in line with the gender equality policy,
- manuals and handbooks as an important source of information on gender equality,
- none of the above methods of education.

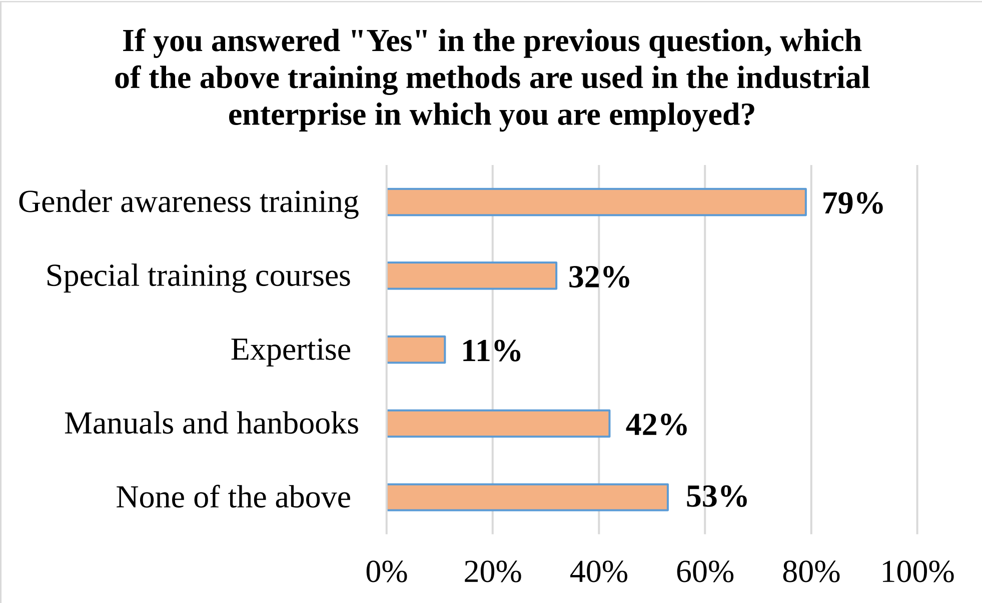

Fig. 2 Respondents' answers to question 9 of the questionnaire

Respondents' answers to question 9 are shown in Fig. 2. 79% of respondents reported that they use gender awareness training in the industrial enterprises where they are employed. 53% of respondents reported that they do not use any of the above-mentioned gender equality training methods in the enterprise 42% of respondents reported that they use gender equality manuals and guides in the enterprise and in 32% of large industrial enterprises there are even special courses for those responsible for introducing gender mainstreaming in the enterprise. Only 11% of respondents reported that the company has gender equality expertise, where gender equality specialists help individuals to put what they have learned into practice.

RQ3: *What obstacles do the employees of large industrial enterprises perceive in connection with the implementation of the gender equality policy?*
Based on the respondents' answers to question 15 of the survey, we also found the answer to the third research question RQ3.
Question 15 was: "What obstacles do you perceive in relation to the implementation of gender equality policy?"
Respondents' answers to question 15 of the questionnaire are shown in Fig. 3. 29% of respondents indicated that they perceived a lack of trained staff in this area as a barrier to gender equality implementation. The next most frequently identified barrier is lack of time, cited by 28% of respondents. 27% of respondents indicated that they perceived a lack of communication within the company as a barrier. Other barriers related to the implementation of gender equality include the refusal of gender equality. 19% of respondents indicated that gender equality is refused by employees and 13% of respondents indicated that gender equality is refused by the management. 12% of respondents indicated that they perceive poorly defined goals in this area as a barrier and 6% of respondents indicated that they perceive high costs as a barrier to the implementation of gender equality. 21% of respondents do not perceive any barriers related to the implementation of gender equality. Respondents were also given the opportunity to give their own answer to this question. They cited answers such as "more men apply for professional topics; not being able to hire more women due to the nature of the work; Korean culture being dismissive of women; society's lack of interest in addressing these issues; and the physical burden" as barriers related to gender equality.

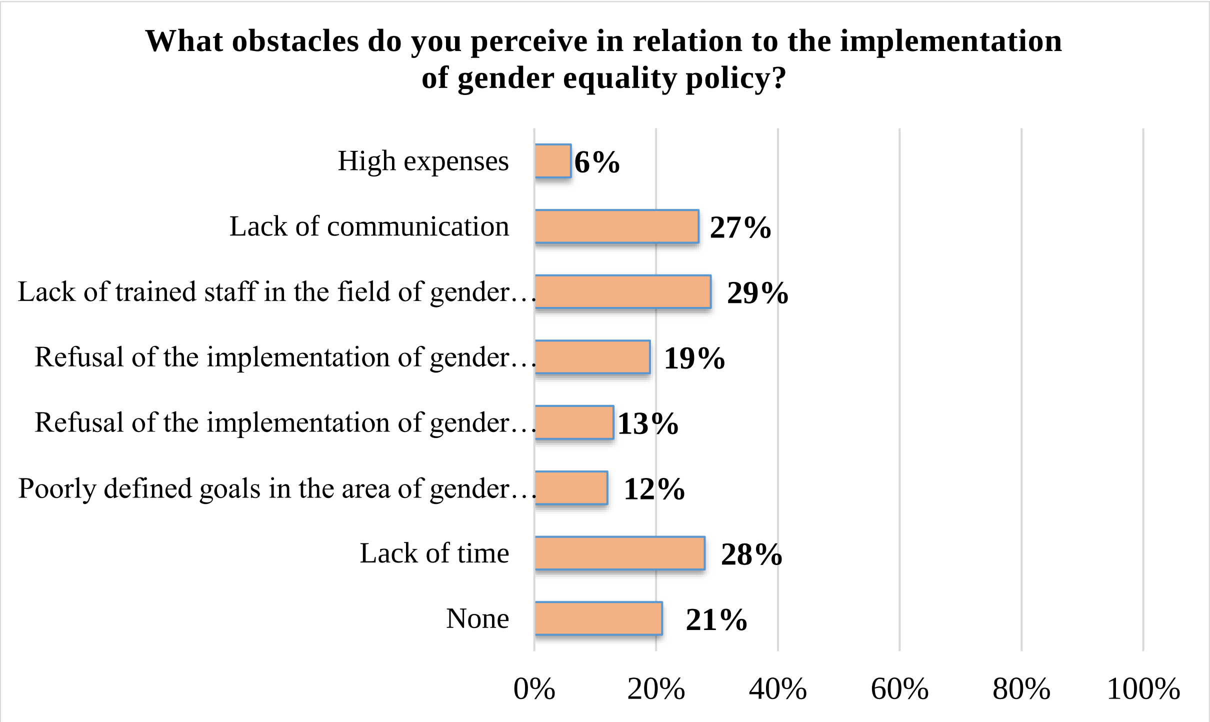

Fig. 3 Respondents' answers to question 15 of the questionnaire

Conclusion

The questionnaire survey revealed several significant findings in terms of the current state of gender equality in large industrial enterprises in Slovakia. Despite progress in this area, there are still many gaps and obstacles that prevent the hierarchy of the company structure between men and women from being equalized. Managers of large industrial enterprises in Slovakia should realize that it is not enough to be familiar with the issue and to have it mentioned in the vision of the enterprise, but the most important for progress is precisely the implementation of the various forms of improving gender equality, which must be subsequently monitored within the framework of a well-defined gender equality plan. The responses of the respondents showed that many large industrial enterprises do not have a gender equality plan in place. Developing a gender equality plan that is fully supported by senior management and senior staff will help to raise the profile of gender equality and ensure a collective understanding of the importance of the plan. Improving gender equality in the workplace is certainly a challenge, as there are certain obstacles that need to be addressed in setting up, implementing, managing or monitoring the various steps defined in the gender equality plan.

The questionnaire survey confirmed that respondents perceive many obstacles to the implementation of gender equality. 29% of respondents stated that they perceive the lack of trained staff in this area as an obstacle to the implementation of gender equality. There is certainly room for improvement in gender equality training, as the questionnaire survey showed that 48% of large industrial enterprises do not train their employees in this area, which means that employees often do not even know the positive benefits of improving gender equality. We believe that well implemented gender education can bring about a change and a shift in the understanding and enforcement of this issue. Respondents also cited rejection of gender equality on the part of employees or management as a possible barrier to implementing gender equality. This rejection often stems from a lack of knowledge about the issue and the benefits

that gender equality brings. However, without the support of top management, improving gender equality is doomed to failure.
In today's digital age, it is important to recognize that the issue of gender equality is also linked to the fourth industrial revolution. If society is to realize the full potential of both sexes, it is essential to address gender inequalities. The current era brings with it many opportunities for both sexes, but gender imbalances prevent women from taking advantage of entrepreneurial opportunities. The technical industry, which has played a key role in driving the fourth industrial revolution, is gender imbalanced. This imbalance already exists in access to education and training for men and women. Dy Martinez et al. [11] conclude that women can benefit from today's digital age. Technological advances allow for more flexible working conditions, meaning that employees can work remotely and thus reduce the mobility required.
Women can offer the business world and especially management a different dynamic, different perspectives, and experience than men. Women's interpersonal skills add value to society and help create thriving organizations. Attracting more women into the workplace can create new opportunities for the business world, while encouraging collaboration between men and women. Shared decision-making between men and women is more multidimensional and complex. Women millennials (Generation Y) are more pervasive in the labor market than older women from Generation X or the post-war generation [12]. This is also due to the digital age and its associated access to technology. Women around the world are increasingly inspired to achieve career success. The availability of resources and awareness is helping women engage with the business world more than ever before. We anticipate that women will continue this trend. Achieving gender equality in the workplace will take time, but women in business is a trend that can and should continue to grow.

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HUMAN-MACHINE COLLABORATION: A COMPARATIVE ANALYSIS OF INDUSTRY 4.0 AND INDUSTRY 5.0

Barbara BARILOVÁ

Abstract: The aim of this article was to compare the collaboration between employees and machines in the context of Industry 4.0 and Industry 5.0 and to identify the relationship between employees and machines in production. We have identified advances in Industry 5.0 in the collaboration between employees and machines, which for companies means an increase in production and overall efficiency. Our findings help to understand the evolution of the relationship between labor and machines and identify the benefits that flow from it.

Keywords: Industry 4.0, Industry 5.0, Engineering, Automation, Robotics

Introduction

The fourth industrial revolution, known as Industry 4.0, marked a significant milestone in the history of manufacturing. It brought forth a new era of digitalization, automation, and connectivity, transforming traditional factories into intelligent and interconnected systems. However, as technology continues to advance at an unprecedented pace, a new wave of industrial evolution, known as Industry 5.0, is emerging. Industry 5.0 represents a paradigm shift that emphasizes the collaboration and coexistence of humans and machines in the manufacturing process. It recognizes the unique strengths and capabilities of both, aiming to create a harmonious working environment where human creativity, intuition, and problem-solving skills are complemented by the efficiency and precision of machines. Unlike the complete automation of Industry 4.0, Industry 5.0 seeks to strike a balance between the human touch and technological advancements. In this research article, we delve into the comparison between Industry 4.0 and Industry 5.0, specifically focusing on the aspect of human-machine collaboration. We explored the evolving relationship between humans and machines in the manufacturing sector and examine the technological advancements that have facilitated this collaborative environment. By analyzing the advancements in Industry 5.0, we aimed to shed light on the transformative potential of this new industrial era. Our research highlights the benefits and challenges of human-machine collaboration and identifies the key differences between Industry 4.0 and Industry 5.0. We sought to provide valuable insights into the transition from Industry 4.0 to Industry 5.0. By understanding the evolving dynamics between humans and machines, we can better grasp the potential impact of this paradigm shift on manufacturing processes, job roles, and the overall future of work. In the following sections, we explored the technologies and principles that define Industry 4.0 and Industry 5.0, analyzed the level of human-machine collaboration in each stage, compared their impacts on the workforce, and discussed the potential implications for the manufacturing industry as a whole [1].

Industry 4.0: Automation and machine assistance

Industry 4.0, often referred to as the fourth industrial revolution, introduced a wide range of transformative technologies that revolutionized manufacturing processes. At its core, Industry 4.0 leveraged technologies such as the Internet of Things (IoT), artificial intelligence (AI), and robotics to create a highly connected and intelligent manufacturing ecosystem [5]. The advent of IoT enabled the interconnectivity of various devices, sensors, and machines within the manufacturing environment. This connectivity facilitated the seamless exchange of information and data, allowing for real-time monitoring, analysis, and decision-making. AI, on the other hand, empowered machines with the ability to learn, reason, and make autonomous decisions, enabling them to perform tasks that were once exclusively within the domain of human capabilities. One of the defining characteristics of Industry 4.0 was the emphasis on automation and machine assistance. Automation played a crucial role in streamlining and optimizing manufacturing processes by reducing human intervention, improving efficiency, and minimizing errors [14]. Machines were equipped with advanced sensors, actuators, and control systems, enabling them to perform repetitive and labor-intensive tasks with precision and consistency. Machine assistance in Industry 4.0 went beyond mere automation [4]. Machines were integrated into the decision-making process, leveraging AI algorithms and data analytics to analyze vast amounts of information and provide valuable insights for process optimization. These intelligent machines could identify patterns, detect anomalies, and make data-driven recommendations, empowering manufacturers to improve productivity, quality, and overall operational efficiency. The impact of Industry 4.0 on the workforce and job roles was significant. While automation and machine assistance led to increased productivity and efficiency, they also raised concerns about job displacement [15]. Routine and repetitive tasks previously performed by humans were increasingly being automated, leading to a shift in the nature of work. However, Industry 4.0 also created new job opportunities, such as the need for skilled workers to operate and maintain advanced machinery, data analysts to derive insights from the collected data, and AI experts to develop and fine-tune intelligent algorithms. The workforce had to adapt and acquire new skill sets to thrive in the Industry 4.0 era. The demand for digital literacy, data analytics, programming, and problem-solving skills increased, highlighting the importance of continuous learning and upskilling. Moreover, human workers began to assume more supervisory and collaborative roles, working alongside machines to optimize processes, make complex decisions, and leverage their creativity and problem-solving abilities. Overall, Industry 4.0 brought a significant transformation in manufacturing through automation and machine assistance. It reshaped the workforce by redefining job roles, demanding new skills, and necessitating a shift towards collaboration between humans and machines. This sets the stage for further exploration of the evolving dynamics between humans and machines in the subsequent stage of industrial evolution, Industry 5.0. [3]

Industry 5.0 represents the next phase of industrial evolution, building upon the foundations laid by Industry 4.0. Unlike its predecessor, Industry 5.0 emphasizes augmented collaboration and co-creation between humans and machines in the manufacturing process. It recognizes the unique strengths of both entities and aims to create a harmonious working environment that combines human creativity, intuition, and problem-solving abilities with the efficiency and precision of machines. At the core of Industry 5.0 is the belief that human workers and machines are not substitutes for each other, but rather complements. The focus shifts from complete automation to leveraging the strengths of humans and machines in a symbiotic manner. This paradigm envisions a future where machines become intelligent assistants, working alongside humans to enhance productivity, innovation, and customization.

Industry 5.0 leverages advanced technologies such as robotics, augmented reality (AR), cognitive systems, and collaborative platforms to foster augmented collaboration and co-creation. Robots are designed to collaborate directly with humans, assisting them in tasks that require physical strength, speed or precision. Augmented reality technologies provide real-time guidance and information overlays, enabling workers to interact with digital content in their physical environment [7]. The concept of co-creation in Industry 5.0 involves humans and machines working together to develop innovative solutions. This collaborative approach encourages human workers to leverage their creativity, critical thinking, and problem-solving skills, while machines provide real-time data analysis, simulations, and predictive capabilities. The combination of human ingenuity and machine intelligence leads to new levels of productivity and innovation in the manufacturing process. Through case studies and real-world examples, Industry 5.0 showcases the potential of augmented collaboration and co-creation. Manufacturing companies are implementing collaborative robots (cobots) that can work side by side with humans on assembly lines, resulting in increased efficiency and flexibility[8]. Virtual and augmented reality technologies are being utilized to enhance training programs and provide immersive simulations for workers. Cognitive systems are being employed to assist in complex decision-making processes, leveraging data-driven insights for improved outcomes. The shift towards augmented collaboration and co-creation in Industry 5.0 has significant implications for the workforce. It demands a new set of skills, including the ability to collaborate effectively with machines, adapt to rapidly evolving technologies and manage the complexities of human-machine interactions. Workers are encouraged to embrace lifelong learning, upskilling, and reskilling to stay relevant in this evolving industrial landscape. In conclusion, Industry 5.0 represents a paradigm shift towards augmented collaboration and co-creation between humans and machines. By harnessing the strengths of both entities, Industry 5.0 aims to unlock new levels of productivity, innovation, and customization in the manufacturing process. The implementation of advanced technologies and the cultivation of a collaborative mindset have the potential to reshape the workforce and create new opportunities for success in the future of manufacturing.

Tab. 1 Comparison of Industry 4.0 and Industry 5.0

	Industry 4.0	Industry 5.0
Focus	Automation and machine assistance	Augmented collaboration and co-creation
Human-Machine Interaction	Limited collaboration, machines assist in tasks	Direct collaboration between humans and machines
Technological Emphasis	IoT, AI, robotics	Robotics, augmented reality, cognitive systems
Workforce Impact	Job displacement concerns, need for upskilling	Emphasis on upskilling, collaboration skills
Efficiency and Optimization	Streamlined processes, improved efficiency	Enhanced productivity and innovation through collaboration
Key Challenge	Job displacement, reskilling requirements	Cultural shift towards collaboration and innovation

Skills Required	Digital literacy, problem-solving abilities	Collaboration, adaptability, and rapid learning
Future Outlook	Continuing automation, digital transformation	Augmented collaboration driving innovation and customization

Source: Author’s own research

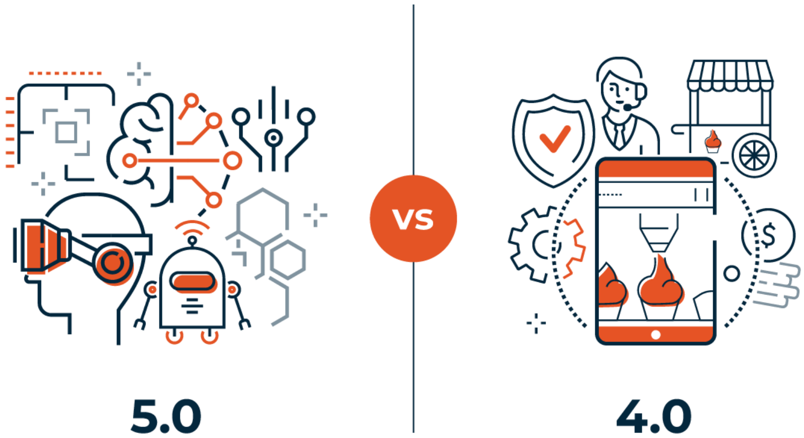

Fig. 1 Industry 5.0 vs Industry 4.0 [9]

Industry 4.0 focuses on automation and machine assistance while Industry 5.0 takes a step further by emphasizing augmented collaboration and co-creation. Industry 5.0 aims to unlock new levels of productivity, innovation, and customization by leveraging the unique strengths of humans and machines [10]. This shift requires the workforce to adapt their skills and mindset to foster effective collaboration and harness the potential of this evolving industrial landscape [2].
A study by PwC estimates that the adoption of AI, IoT, and robotics, could add $15.7 trillion to the global economy by 2030 [6]. AI may replace certain job functions but it also has the potential to create new job opportunities. The development, deployment, and maintenance of AI systems will require skilled professionals, such as AI engineers, data scientists, and machine learning experts. Additionally, new roles may emerge in areas such as AI ethics, governance, and explainability. AI systems can augment the capabilities of human workers, making them more productive and efficient, because it can provide data analysis, decision-making, and providing real-time insights. The collaboration between humans and AI can enhance job performance and lead to improved outcomes [12] [13].

Conclusion

The transition from Industry 4.0 to Industry 5.0 represents a significant shift in the manufacturing landscape. Industry 4.0 laid the groundwork by introducing automation and machine assistance, streamlining processes, and improving efficiency. However, it also raised concerns about job displacement and required the workforce to acquire new skills to adapt to changing job roles. Industry 5.0 takes a step further by emphasizing augmented collaboration and co-creation between humans and machines. It recognizes the unique strengths of both entities and aims to create a harmonious working environment that combines human creativity, intuition, and problem-solving abilities with the efficiency and precision of machines. This paradigm shift has the potential to unlock new levels of productivity, innovation, and customization in the manufacturing process. The adoption of advanced technologies, such as robotics, augmented reality, cognitive systems, and collaborative platforms enables machines to work alongside humans as intelligent assistants. This collaborative approach encourages human workers to leverage their creativity, critical thinking, and problem-solving skills, while machines provide real-time data analysis, simulations, and predictive capabilities. Industry 5.0 places a human-centric focus on the well-being and satisfaction of workers. It acknowledges the need for upskilling and lifelong learning to thrive in this collaborative environment. The shift towards Industry 5.0 requires the workforce to adapt their skills and mindset, embracing the opportunities for collaboration and innovation. As we continue the journey towards Industry 5.0, it is essential for organizations, policymakers, and individuals to embrace this new paradigm. Efforts should be made to foster a culture of collaboration, provide continuous learning opportunities, and ensure the equitable distribution of benefits arising from the collaboration between humans and machines. By embracing augmented collaboration and co-creation, Industry 5.0 has the potential to reshape the manufacturing sector, driving economic growth, job creation, and sustainable development.

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MARKETING MANAGEMENT OF INNOVATIVE ENTERPRISE DEVELOPMENT

Naqib DANESHJO – Zuzana FRANCOVÁ

Abstract: Forms, methods and technologies of marketing management in the practice of market participation of organizations are increasingly important and in this context it is important to take into account the impact of market environment factors, calculate the economic feasibility of commercialization of a new idea, predict business risks, determine the product positioning strategy, determine the objective price of the product and ensure its adaptation to changes in the market, use effective marketing communications, as well as the optimal methods of withdrawal from the market
Keywords: Innovative marketing, management, development, market, product.

Introduction

Marketing management is a philosophy of market participation aimed at increasing business activity to meet the reasonable healthy needs of customers, their consumption needs. This philosophy is reflected in the individual approach, which represents not only the ability to create integrated marketing programs, taking into account the abilities and characteristics of each customer, but also the ability to work in advance, to carry out revolutionary projects and to respond immediately to the demands of the product market. Changes in the management structure in the 21st century indicate a characteristic strengthening of the role of marketing in practical management and demonstrate their impact on the development of managerial marketing concepts. The formation of marketing as a concept for organizing business activity in a market environment could not occur in isolation from the formation of management theory and practice. Moreover, as the analysis shows, each stage of marketing development is clearly connected with economic preconditions, a certain period of development of management concepts. The concept of innovative marketing management of the organization is revealed in the form of a document on the development of an enterprise system that combines objectives, principles and functions. The main goals of marketing management:

- Maximising the degree of consumption satisfaction due to synchronisation of activities, sales volumes and service availability,
- Ensuring a wide selection of goods and services to meet the material and spiritual needs of the community in a timely and quality manner,
- Maximising quality of life, quality of choice based on the use of environmentally friendly production technologies, the introduction of safe goods and services and the creation of a cultural environment,
- Expanding the strategic area of market presence based on sales intensification and the use of virtual marketing opportunities,
- Creating a positive reputation and image as a result of achieving synergies from the integrated use of brand, merchandising, trade marketing and partnerships.

Organisation of marketing in the business management system

The strategic goal of innovation management in a company is to create a special innovation culture that contributes to increasing economic, social and environmental efficiency and competitiveness on domestic or global markets.

Tab. 1 Set of basic objectives of innovation management of the enterprise

Component of organisational culture	The main objectives for the development of an innovative culture
Material or production culture	• Introduction of information and computer technologies for production process management, automated and robotic production lines. • Improving the quality and competitiveness of products through the use of unique and radical cutting-edge technologies based on their technical novelty, achieving multifunctionality of manufactured products or, on the contrary, ease of use and mini-functionality of products. • Changing the culture of working conditions on the basis of the addition of basic characteristics ensuring sanitary, hygienic and physiological conditions of work activities, psychological, social and aesthetic conditions contribute to improving the quality of working life. • Development of the information culture of the enterprise as a system of values that ensures the creation and accumulation.
Spiritual culture	• Shaping the culture of human resources, openly accepting innovation, promoting creativity and intellectual development, and thus stimulating various types of innovation activities of the enterprise through a system of maximizing the value of knowledge and business capital. • Formation of an innovative business culture of the parent company's management, thereby stimulating the spread of the value of innovative development in all areas of the company's activities. • Formation of a favorable moral and psychological climate in cross-functional teams providing scientific and technological research, development work and accelerated struggle for new types of products. • Innovative personal development through a system of updating the needs of the company's employees in the areas of education, professional development, entrepreneurship, creative and intellectual growth, motivation for a healthy lifestyle and organizational commitment.
Ecological culture	• Creating a distinctive corporate image; a concept based on the concepts of environmental value and safety.

Modern elements of the organization with innovative entrepreneurial activities:

- Strengthening the decentralisation of innovation management,
- Regional orientation of research and development laboratories and marketing services.
- Integration with research institutes and universities in basic research,
- Use of outsourcing,
- Reorganisation of companies to consolidate R&D and marketing departments into a single innovation management unit,
- The transition to an integrative organisational structure, i.e. the structure of the retail network, should be determined according to the principle of the internal market,
- Active use of venture capital, cross-functional teams, project teams and coordination centres,
- Creating technology intelligence units.

Marketing control of innovation activity

Marketing control is a continuous, systematic and unbiased control and evaluation of the situation and processes in the field of marketing. Monitoring of the implementation of planned innovative marketing programmes as well as comparison with the intended marketing objectives and development directions is carried out within the framework of current and strategic plans. The monitoring of marketing activities in an innovative company results in answers to the main control questions such as whether what was desired has been achieved, if certain objectives have not been achieved, what the reasons are, what changes are needed in the company's plans and in its innovative projects to ensure their implementation. This network of control is not just stating facts, measuring results. Marketing control usually takes place in four phases:

1. Setting goals and standards.
2. Clarification of the actual values of the indicators.
3. Comparison.
4. Analysis of comparison results.

Roles and objectives of marketing control:

- Determine the degree of achievement of the target (analysis of variance),
- Identify opportunities for improvement (feedback),
- To check to what extent the enterprise is adaptable to environmental changes and meets the specified requirements.

The result of the control task is to verify the correctness and effectiveness of the implemented marketing concept by comparing the planned and actual values and identifying the causes of deviation. The monitoring uses data from accounting systems (sales control, profit calculation, etc.), data from market surveys (image analysis, level of awareness). The main requirements for the values used as a basis for comparison are comparability of the data, i.e. relatively constant conditions, and the certainty that the basis for comparison represents a value that is really worth striving for. Main types of control:

1. Sales control: Sales analysis is possible for the entire enterprise and for different groups and objects (regions, customers, products, distribution channels, etc.). The analysis makes it possible to determine what role individual factors such as price or quantity have played.
2. Market share control: market share is the ratio of the companies' sales to the sales of the product as a whole, to the sales of the industry leader or to the sales of a few main competitors. A high market share provides an advantage over competitors in terms of cost reduction opportunities.
3. Analysis of the results of the sales services activity.

For effective governance, it is important not only to get the state of market affairs right, but also to get the impact measures right - what needs to be done to improve the market situation for innovation. Controlling marketing activities involves addressing the following main tasks:

1. Determining the parameters of marketing activities in an innovative firm that are subject to control.
2. Determination of actual results achieved by control parameters. Sources of information on actual results achieved are marketing reports of sales departments or accounting data of the innovative company.
3. Comparison of planned and actual performance indicators.
4. Determine the reasons for the deviation of the actual indicators from the planned ones.
5. Development of measures to improve innovation activities and adaptation of existing plans, development of new projects.

Tab. 2 Stages of GAP analysis to improve innovation marketing

Stage	Table of Contents
Determination of the scope of the analysis and its tasks	The dynamics of planned and actual values of marketing indicators (e.g. sales volume, investment programme, marketing innovation expenditure of the current period, market share, etc.) are analysed.
Construction of the predicted and actual change curve of the selected indicator of the GAP analysis graph	Construction of the projected and actual change curves of the selected indicator of the GAP analysis graph.

Definition and description of gaps: list of "obstacles"	A list of gaps between indicators shall be compiled, highlighting the significant ones, and their causes shall be analysed with a view to developing measures to reduce the gaps.
Developing a set of actions to overcome obstacles	Events or new project marketing activities are being developed to help bridge the gaps.
Work schedule with deadlines and obligations	A timetable of innovation marketing activities is created with a breakdown of work by deadline and implementer.
Results tracking and GAP analysis	Analyzing and controlling the implementation of marketing activities and conducting iterative GAP analysis to track results and adjust activities and the project as a whole.

Marketing indicators and indicator method to assess the innovation potential of the enterprise

An innovation policy is a set of management methods that ensure the acceleration of the processes of integration of all types of innovation in order to create a favourable climate in the enterprise that stimulates innovation in all areas of industrial and business activities. With many companies moving towards open innovation, there is a significant change in the functions performed by R&D departments in the organisation. With a relative surplus of external expertise, companies are focusing their R&D departments on these tasks:

- Identification, analysis, selection and integration of the entire body of disparate knowledge that exists outside the organisation and is of significant value to it,
- Supplementing own knowledge at the expense of "foreign" knowledge created outside the enterprise,
- Integration of "external" and "internal" knowledge into more complex combinations of new knowledge, enabling the creation of new systems and models,
- Generating additional revenue and profits by selling our research results to other companies to use in their own systems.

This change in emphasis and priorities is leading to significant organisational changes, for example, a change in the approach to performance appraisal of R&D staff, their promotion, career development, etc. An organisation's innovation potential is characterised by the sum of its resources and capabilities needed to create, produce and market innovations. The innovation potential of an organisation is characterised by all its resources and capabilities needed to create, produce and market innovations and we can distinguish the following elements of innovation potential:

1. The number and skill mix of staff.
2. Scope of Business.
3. Scale of the business and financial capacity.
4. Technological level of the enterprise.
5. The nature of the market in which the company operates.
6. The innovation environment and infrastructure within which the business operates.

The assessment of the innovation potential of the enterprise is carried out in order to solve the following tasks:

- Determination of the level of innovation potential and its impact on the economy of the enterprise,
- Determination and comparison of the level of the components of the potential in order to identify the main directions of its development,
- Improving the management of innovation potential,
- Determination of the relationship between measures for the development of innovation potential and the sequence of their implementation in enterprises.

The indicator method includes several stages of evaluation of the innovation potential of the enterprise. In the first phase, individual indicators are calculated to characterise the level of the individual components of innovation potential (Table 3).

Tab. 3 Indicators for assessing the innovation potential of an enterprise

Type of business potential	Examples of evaluation indicators
Scientific	• The share of research and development costs in the volume of innovation activity costs, • The share of current R&D expenditure in the volume of R&D expenditure, • The share of R&D capital expenditure in R&D expenditure, • The proportion of rationalisation proposals implemented, • The proportion of staff with an academic degree, • The proportion of innovations put into practice, • The share of own innovation in the total amount of development carried out.
Innovation Management	• The share of innovation managers in the total number of senior managers, • The share of the costs of organisational and managerial innovation activities in the costs of innovation activities, • The share of the running costs of organisational and managerial innovation activities in the costs of organisational and managerial innovation activities.
Innovative investing	• The share of funds earmarked for innovation activities in total investment, • The share of total lending going to innovation activities.
Staff	• The share of innovation employees in the total workforce, • The proportion of staff receiving training and up-skilling, • The share of manufacturing employees with the need to introduce innovative skills, • Share of workers combining professions.
Industrial	• The ratio of the cost of innovation activities to the volume of innovative products, • The ratio of the cost of innovation activities to the cost of commercial products, • The ratio of the volume of innovative products to the volume of commercial products, • The ratio of the cost of technological innovation to the volume of innovation expenditure, • The share of the running costs of technological innovation efficiency in the volume of costs of technological innovation activity, • The share of capital expenditure on technological innovation activity in the cost of technological innovation activity, • The share of the cost of project innovation activity in the cost of innovation activity, • The share of the current cost of design innovation activity in the cost of design innovation activity.
Innovative marketing	• The proportion of specialist marketers involved in innovation, • The share of the cost of promoting innovative products in the total cost of promoting products, • The share of expenditure on the promotion of innovative products in total promotion expenditure, • The share of expenditure on marketing activities for innovative products in the amount of expenditure on innovative activities.

In the second stage, the levels of the individual components of the innovation potential of the enterprise are determined by calculating the square root of the product of the private indicators characterizing the individual components of the innovation potential of the enterprise. In the third stage, there is a generalized level of the innovation potential of the enterprise, which is defined as the ratio of the sum of the products of the level of the individual component of the innovation potential and the corresponding weight to the sum of the weights of the individual components of the innovation potential of the enterprise. The indicator method characterizes the level of innovativeness of the company's potential and helps management to assess the current state, identify reserves to increase the potential and select priority areas for its development. This technique allows you to determine:

- The level of innovation potential in the enterprise over the reporting period.
- The average growth rate of the level of innovation potential.

The economic approach is manifested in the construction of an economic and mathematical model to assess the innovation potential of the enterprise. This methodology for assessing innovation potential characterizes the level of potential and is intended to help the management of the enterprise to analyze the current state, identify reserves for improvement and select priority areas for its development.

Conclusion

In industrialised countries, the marketing concept has been at the forefront of company development for decades. At the same time, it should be noted that the formation of innovative marketing as a scientific discipline has occurred only in recent decades. Innovative marketing is marketing that encompasses an organization's mission, philosophy of thinking, field of scientific research, management style and behavior. It is organic, not imposed innovation, a special type of relationship and complete risk-taking. Under the conditions of financial crisis in the world and the global competitive environment, it is necessary to accelerate the creation of competitive industrial products, export orientation and high profitability, which could promote the diversification of the country's whole economy, ensure its competitiveness among the countries of the world and reduce the dependence of its economy. In this regard, strengthening the role of innovation and marketing in the country's industrial development in the context of global competition is considered to be one of the priority areas for the development of the country's economy. The process of innovation and strategic marketing is indeed a source of information for the management of innovation activities and innovative solutions that can translate the value of innovations from product innovations conditioned by technological innovations, innovations in the organizational structure of the enterprise and in synergy with marketing innovations into changes in quantitative performance indicators and performance in monetary and non-monetary indicators.

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INTEGRATION OF LEAN MANUFACTURING AND ERGONOMICS: A CASE STUDY

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Abstract: If lean manufacturing is implemented in an organisation without ergonomic requirements being considered at the same time, the expected result in the form of increased production productivity may not be achieved. In this context, several authors have highlighted the strong potential for synergies that will arise as a result of the successful integration of lean manufacturing and ergonomics. Aim of the paper is to demonstrate the use of lean manufacturing tools in increasing the productivity of casting aluminum alloys while taking into account ergonomic requirements. We adopted a hybrid research design and conducted a single case study. This case study explores an industrial implementation of a robotic cell in production line for the production of battery covers for electric/hybrid vehicles, integrating ergonomics and lean manufacturing principles.

Keywords: Value Stream Mapping, CERAA, Key Indicator Method, REBA.

Introduction

The results of several research studies (e.g. [1], [2], [3]) suggest that lean manufacturing contributes significantly to the increase in employee-perceived workload. One reason for this is that efforts to reduce waste in the work process result in the elimination of activities that do not add value. This can lead to an increase in the constraints associated with performing work operations and, at the same time, a decrease in the possibility of workload variability. The result is then often monotonous work characterized by stereotyped manual activity with a high incidence of identical work tasks or work at a forced work pace with limited opportunities for breaks and rest, which has a negative impact not only on work performance but also on the health of the person in the work process.

It is clear from the above that if lean manufacturing is implemented in an organisation without ergonomic requirements being considered at the same time, the expected result in the form of increased production productivity may not be achieved. Although at first glance it may seem that the objectives of lean manufacturing and ergonomics are diametrically opposed, this is not entirely the case. As an example, we can look at the desire to eliminate one of the basic types of waste: unnecessary movements. Unnecessary movements cause increased employee fatigue, which can result in reduced product quality and increased production time. For this reason, activities that contribute to the reduction of unnecessary movements can be considered beneficial from both a lean production and ergonomics perspective. In this context, several authors have highlighted the strong potential for synergies that will arise as a result of the successful integration of lean manufacturing and ergonomics.

Nunes [4] proposed a methodological framework for integrating Lean Six Sigma (LSS) and ergonomics. Alsaffar and Ketan [5] proposed a diagnostic expert system in the form of a software tool that was developed in the Visual Basic 6 environment. The software tool is based on the idea of combining methods aimed at identifying and reducing lost time and ergonomic risks related to the biomechanical and postural requirements of work activities. Brito et al. [6] highlighted the possibility of reducing machine retyping time while improving working conditions from an ergonomics perspective. The case study was carried out in a tap manufacturing plant where a high rate of absenteeism and complaints from employees related to excessive strain on the limbs was noted. By applying the SMED (acronym for term Single Minute Exchange of Die) method, the retyping time was reduced by 46 percent and at the same time the risk of damage to the support and locomotion system was reduced to an acceptable level through the REBA (acronym for term Rapid Entire Body Assessment) method. Jarebrant et al. [7] extended the traditional lean manufacturing VSM (acronym for term Value Stream Mapping) tool to include an ergonomic dimension, resulting in the new ErgoVSM tool. The ErgoVSM tool is based on visualization and dialogue to support the process from mapping the current state to the creation of a future state value stream, including a list of actions needed to achieve it. The ergonomic assessment considers the following areas: working postures, muscle strength, variability of physical load and resting ability. Arce et al. [8] further extended the ErgoVSM method to assess mental workload. The assessment of mental workload is carried out through the subjective response of the employee using the NASA TLX method. Botti et al. [1] developed a linear mathematical model that can be used to determine the optimal placement of manual and automated jobs in a hybrid assembly line. The optimization criteria are based on the reduction of work-in-process quantity and total cost, taking into account at the same time, in the case of manual jobs, the risk of health damage due to high-frequency repetitive activities in manual handling through the OCRA (acronym for term Occupational Repetitive Actions) evaluation method. Oliveira et al. [9] demonstrated the synergistic effect of lean manufacturing and ergonomics through the example of material flow optimization in order to increase labour productivity and improve working conditions. By modifying the original logistics processes, they were able to reduce by 94 percent the walking distance that operators have to cover in order to secure the necessary material between the warehouse and the workplace. Yusuff and Abdullah [10] conducted an ergonomic analysis based on observation and evaluation of non-value adding work movements. They used movement time studies, a standardized Nordic questionnaire, and the RULA method (acronym for term Rapid Upper Limb Assessment) in their evaluation. Based on the results of the analysis, ergonomic interventions were designed to eliminate or reduce unnecessary movements as much as possible. The results of the study confirmed that an inappropriate combination of work positions and work movements not only increases the risk of cumulative trauma disorder, but also decreases the productivity and efficiency of the employee. Colim et al. [11] analyzed the synergism of integrating lean manufacturing principles and ergonomics through the implementation of a collaborative robotic assembly workstation. The evaluation of the workplace before and after the implementation of the robotic technology was carried out by determining various key performance indicators using a time study and direct observation. The subjects of the ergonomic analysis were 40 work positions during assembly operations. Three methods were used to evaluate the workstations: the RULA, the RSI (acronym for term Revised Strain Index) and the KIM (acronym for term Key Indicator Method). In addition, operators' attitudes towards the introduction of the robot in the assembly workplace were investigated by means of questionnaires. The aforementioned multi-method approach demonstrated that the implementation of a collaborative robotic assembly workstation achieved: a reduction in production times, an improvement in working conditions and an increase in personal well-being at work from the operators' point of view. Pekarčíková et al. [12] focused on application of simulation tools in creation of the casting process model and simulation of technological operations on the workplace of casting processing. They optimized the workplace layout in terms of ergonomics by using the Tecnomatix Jack software module and Microsoft Kinect.

Aim of the paper is to demonstrate the use of lean manufacturing tools in increasing the productivity of casting aluminum alloys while taking into account ergonomic requirements.

Materials and Methods

Similarly as Colim et al. [11] we adopted a hybrid research design and conducted a single case study. This case study explores an industrial implementation of a robotic cell in production line for the production of battery covers for electric/hybrid vehicles, integrating ergonomics and lean manufacturing principles. We assessed the workplace before and after the implementation of robotic technology and measured different indicators through a time study and direct observation. Originally, the operator manually transferred the castings from the transport basket to the storage basket for heat treatment (see Fig.1). Subsequently, after heat treatment and cooling of the castings, operator again manually handled them from the storage basket to the transport basket. After intervention, operator just lifts the castings from the transport basket to the conveyor and the robot arm then places the castings in the storage basket.

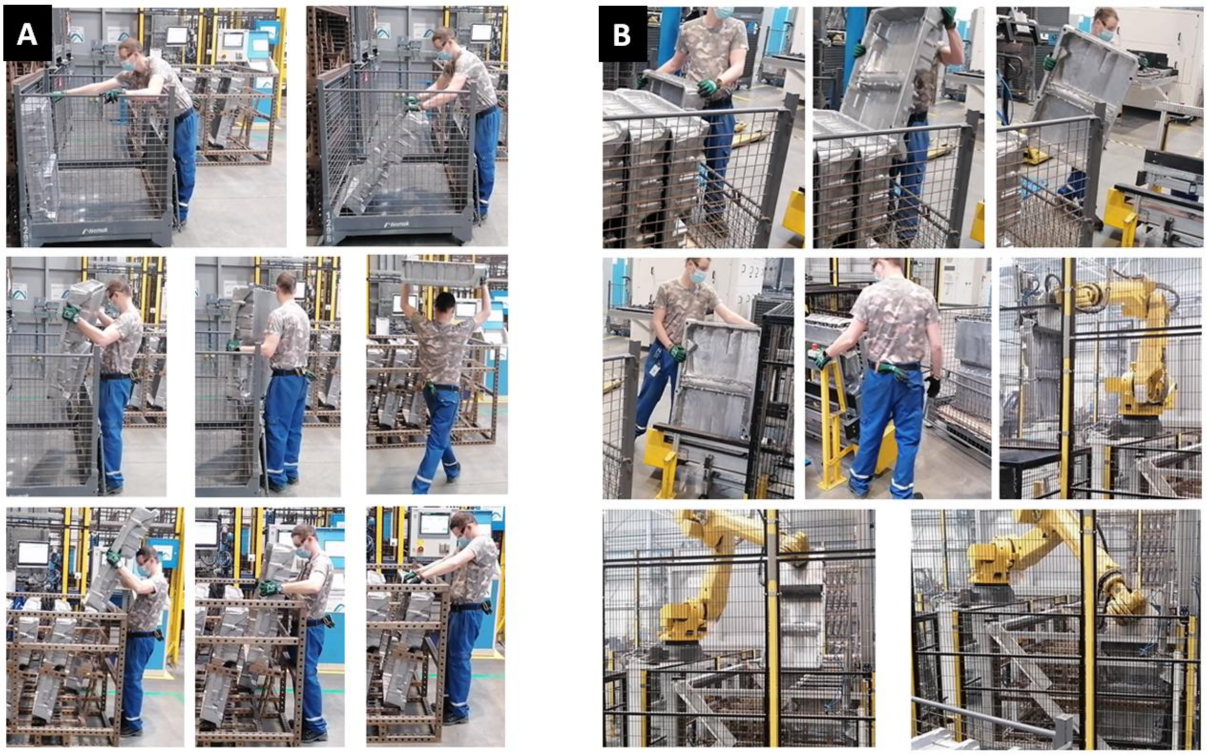

Fig. 1 Manual handling of castings: A – before intervention, B – after intervention [13]

Value stream mapping method was used to identify non-value tasks. Basket load/unload task was considered as non-value adding task but necessary so these task cannot be eliminated, just reduced as much as possible.
Ergonomic assessment was performed using following methods:

- CERAA (acronym for Ceit Ergonomic Analysis Application) module Evaluation of working postures and dimensional requirements and module Assessment of manual handling,
- Key Indicator Method for assessing physical workloads with respect to manual lifting, holding and carrying of loads (KIM-LHC),
- Rapid Entire Body Assessment (REBA).

Results and Discussion

Comparison of the workplace before and after the implementation of robotic technology is presented in Table 1.

Tab. 9 Comparison of the workplace before and after the implementation of robotic technology

Indicator	Before intervention	After intervention
Production lead time	3618 seconds	3587 seconds
Number of operators	2	1
KIM-LHC score Physical loads	101,5 points High intensity of load	49 points Intensity of load is slightly increased
REBA score Task – casting carrying Task – placing the cast in the basket	8 points High risk 8 points High risk	4 points Medium risk - -
CERAA Working postures Maximal full shift weight of the load	Limit exceeded Limit exceeded	Limit not exceeded Limit not exceeded

The results of the assessment of working positions through the CERAA application before intervention indicate a potential risk of increased physical strain on operator (see Figure 2). During the evaluation of the trunk forward bend, it was found that the cumulative duration of the unacceptable working position (trunk forward bend > 60°) for the entire shift is 11,44 minutes.

Fig. 2 Working postures evaluation in CERAA before intervention [13]

During the head tilt assessment, it was found that the cumulative duration of the unacceptable working position (head tilt > 40°) for the entire shift is 29,33 minutes. During the evaluation of upper limb flexion, it was found that the cumulative duration of an unacceptable working position (limb flexion > 60°) for the entire shift is 24,5 minutes. The total working time in the work shift in individual unacceptable work positions thus exceeds the permitted 30 minutes. When evaluating the maximum full shift weight of the load, it was found that the indicative weight value is observed only in the case of operators in the age category of 18 to 29 years. In the remaining age categories, the maximum full shift weight is exceeded by 8.4% (30-39 years), by 30% (40-49 years), and by 56% (50-60 years).
The results of the assessment of working positions after the implementation of robotic technology do not indicate a potential risk of increased physical load on the operator. During the evaluation of the trunk forward bend, it was found that the cumulative duration of the unacceptable working position (trunk forward bend > 60°) for the entire shift is 2,86 minutes. When evaluating head rotation, it was found that the cumulative duration of an unacceptable working position (head tilt > 15°) for the entire shift is 18,33 minutes. During the assessment of upper limb flexion, it was found that the cumulative duration of an unacceptable working position (upper limb flexion > 60°) for the entire shift is 7,33 minutes. Thus, the total time of work in a work shift in individual unacceptable work positions does not exceed the permitted 30 minutes. During the evaluation of the trunk forward bend, it was found that the cumulative duration of the conditionally acceptable working position (trunk forward bend: 40°- 60°) for the entire shift is 2,2 minutes. When evaluating head tilt, it was found that the cumulative duration of a conditionally acceptable working position (head tilt: 25°- 40°) for the entire shift is 11 minutes. During the assessment of upper limb flexion, it was found that the cumulative duration of a conditionally acceptable working position (upper limb flexion: 40°- 60°) for the entire shift is 14.67 minutes. The total working time in a work shift in individual conditionally acceptable work positions does not exceed the permitted 160 minutes.

Conclusion

Current trends in manufacturing, which are based on customisation and gradually customised production, are becoming the main initiator for the development of new manufacturing approaches [14]. As part of its philosophy, lean manufacturing is constantly striving to eliminate or reduce various types of waste. However, practical experience suggests that the use of individual lean production tools often leads to an intensification of work, resulting in increased physical and psychological strain on employees at work. By integrating lean production tools and ergonomic requirements, it is thus possible to create a desired state where the productivity of the production process is maximized while minimizing waste.

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WORKING TIME EFFICIENCY USING THE FACE MASTER 1.7K DRILL RIG ASSEMBLY PROCESS AS AN EXAMPLE

Daniel DĘBOWSKI– Jarosław BRYŁKOWSKI – Paweł JURCZAK – Marek MIZERÁK

Abstract: The paper presents the optimisation of the assembly process of the Face Master 1.7K self-propelled drilling machine by increasing the efficiency of the working time and reducing time losses. The production stages of the drilling rig, the course of the assembly process and the method of monitoring and controlling the working time of the assembly brigade during the machine assembly process were characterised. The reasons for time losses in the assembly process were identified and measures were taken to minimise them. The results of the control tests carried out on the measurement of assembly time, the analysis, the conclusions from the observations, the suggestions for improvement, the corrective measures and organisational changes implemented and the results of the optimisation were presented.
Keywords: PDCA method, Kaizen, assembly, production system.

Introduction

The production system for self-propelled mining machines at Mine Master Sp. z o.o. consists of the manufacture of steel structures for the chassis frames of mining machines and the assembly of the manufactured chassis structures with subassemblies supplied by external suppliers. The end product is a self-propelled mining machine. Depending on the type and functionality of the machine, a distinction can be made between drilling rigs, bolting machines and support vehicles [1]. Each machine can have several different configurations, according to the needs and requirements of the customer (MTO make-to-order), by which production is considered as a unit or small lot [2]. In the case study analysed in this paper, there is a problem of downtime in the assembly process. Existing time losses are the reason for delays in the timely implementation of the assembly process, resulting in missed delivery dates for the finished machine and financial penalties. The aim of this study is to analyse and optimise the efficiency of the assembly process of the Face Master 1.7K self-propelled drilling machine (Fig. 1) by increasing the efficiency of time use and reducing time losses.

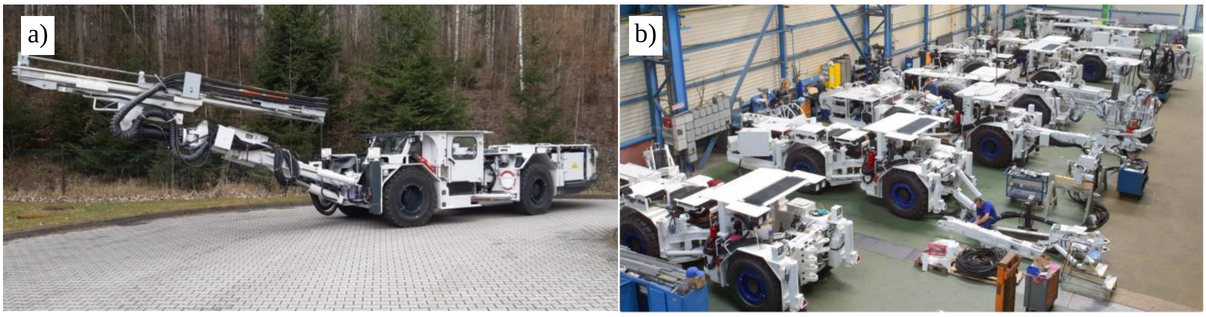

Fig. 1. Face Master 1.7K self-propelled drilling truck: a) finished product, b) on the assembly floor [3].

The production process of the Face Master 1.7K drilling machines takes place on the company's three production halls and is divided into two main stages. The first is the manufacture of the steel structure of the machine chassis. The second is the assembly of manufactured semi-finished steel structures with externally supplied purchase components.

Registration and control of the working time in the production

The working time of the assembly teams is recorded at the assembly station. Each worker logs on to the system with his code for the relevant production order. He then selects the correct work station for the assembly operations he is carrying out. The system records the operator's working time in the specified area. When the activity is completed, the assembler signs in again and the system stops counting the time of the operation. The hours recorded by the system are registered in the production order. The progress of the work and the hours used to complete the order are continuously monitored by the Production Planning and Control Department. The hours counted by the system are processed and sent as a report to the monitoring file.

Scope of research

In order to verify the efficiency of the time spent assembling the machine, an analysis of the existing work process of an assembly brigade at one station with two fitters was carried out. The measurements were carried out during 19 shifts of the assembly process of the FACE MASTER 1.7K self-propelled drill rig. The study was carried out using the continuous observation method, where the observer is constantly present at the workstation. The ORTIM software was used to record times and analyse the results, as well as the activity classification method, which makes it possible to locate areas of process disruption, identify waste and search for areas for improvement. Observation was carried out from the assembly of the tractor frame, through the assembly of the working frame, to the assembly of the complete cab. A list of basic operations was prepared based on general assembly diagrams: chassis, tractor, platform, cab, while detailed operations were described according to diagrams provided by the leader on the bench.

The process of normalising times involves a structure of normative times divided into preparation and completion times and unit times [4]. Unit time consists of complementary time and execution time. Complementary time consists of personnel time and material time. Execution time consists of main time and auxiliary time.

The times of the individual activities that were observed during the study were categorised into areas of running:

- The main time for the clean assembly sub-processes, covering the planned activities of the assembly operation of all components of the Face Master 1.7K machine,
- Supplementary time for segments of the course divided into:
  - tangible fixed supplementary time - activities that are independent of the order and occur during each work shift, e.g. cleaning the workplace at the end of the work shift (statutory time of 10 minutes),
  - tangible variable supplementary time - includes any unscheduled additional activities and interruptions usually resulting from disruptions to the production process, e.g. making corrections, performing rework, disassembly and reassembly, organising the workplace, service calls, waiting for an employee, waiting for tools.
- Conditionally useful time for sections of the run covering activities that serve the work task but are not included in the main time, caused by extraordinary interruptions in the run, occasionally occurring, e.g. locating parts for a machine on the shop floor, additional activities ordered by the leader.
- Personal supplementary time - personal breaks e.g. answering the phone, toileting.
- Rest time - breakfast break, scheduled 20 minutes.
- Lost time - activities that do not serve the work task, e.g. idleness or lack of work.

Results of measurements

A graphical representation of the results of the time use study is shown in Figure 2. It can be seen that the percentage of time spent on planning activities is only 42.13%. The actual variable additional time is 15.62%. On the other hand, wasted time is a worryingly high 32.32%.

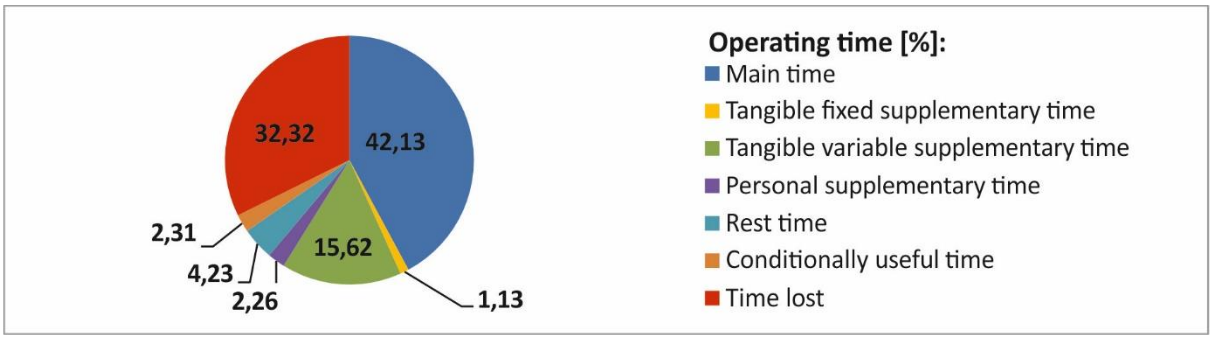

Fig. 2. The structure of the use of working time by type of time

Figure 3 shows the use of working time by individual fitters. The results show a similar level of commitment and work execution. It was observed that fitters spent more than 32% of their time on activities that should not have been (including failing to comply with applicable working hours, dragging out break times, conversations/private matters, missing work, idleness).

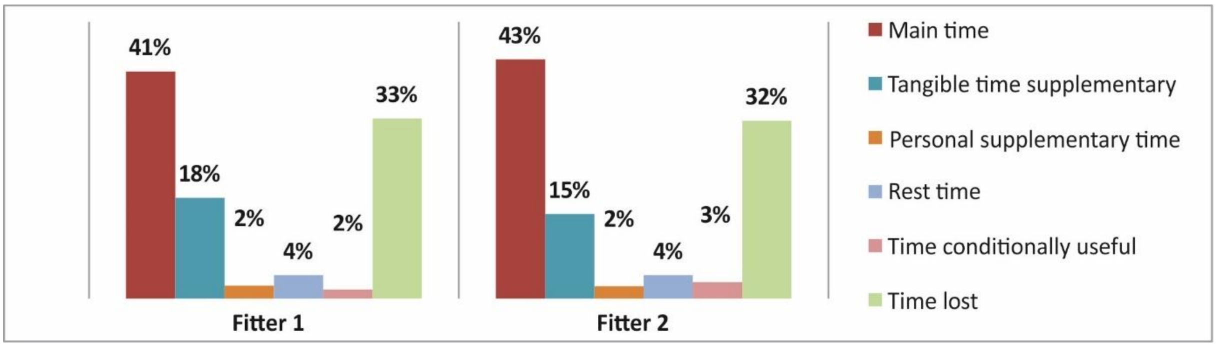

Fig. 3. The structure of the use of the working time of fitters

Employee downtime, which results in lost time, is largely due to waiting time. The most common causes of downtime are: Lack of assembly materials and problems with the assembly of available parts due to incorrectly made or mismatched components. Assembly collisions that occur are also a cause of downtime. Workers are idle and waiting for decisions to be made by authorised personnel, e.g. a designer or technologist, as they are often not in a position to start the next assembly operation until the current activity has been completed.

During the observations, many additional activities were registered. These were related to corrections, reworking or waiting for the removal of nonconformities. These are disturbances that occur in the process. Their additional time to the main time of the process under study was registered at a very high and unacceptable level.

Many additional activities related to making corrections, reworking or waiting for the removal of nonconformities were registered during the observations. These are disturbances that occur in the process, whose additional time to the main time of the process under study was registered at a very high and unacceptable level.

Implementation of changes in the process

Changes to improve the efficiency of the machine assembly process were implemented using the PDCA method with the principles of the Kaizen methodology [5,6,7]:

- A co-ordinator has been appointed to control the flow of steel sub-assemblies between warehouses, assembly halls and the paint shop, with the aim of reducing the level of conditionally usable parts and time wastage.
- A standard procedure has been developed and implemented for the delivery of parts on pallets from the paint shop and warehouse to the assembly station. The parts on the pallets are to be arranged by the paint shop personnel according to the instructions. The pallet with the parts is delivered with the instructions to the parts store or directly to the assembly station. The aim of the measure is to eliminate the problem of searching for parts in order to increase the degree of utilisation of the prime time.
- A log of process assembly discrepancies was created. The supervisor keeps a register for each job, and in a daily report details what caused the problem during assembly and why, how the non-conformity was corrected, and how long it took to make the corrections. The aim of the measure is to reduce the amount of corrections and reworking during the assembly of the machine, in order to reduce the amount of material replenishment time and lost time.
- Reorganisation and standardisation of employee workstations. The ergonomics of the assembly workstations have been improved to increase functionality. This is expected to reduce the problem of frequent walking by employees, thus increasing the utilisation of core time.
- Modular assembly was introduced. Larger assemblies of machine components could be delivered to the workstations as assembled modules. This has made it possible to speed up machine assembly by reducing the number of assembly man-hours. The aim of this measure is to increase the utilisation of core time.

Modernization of the assembly station

The workbench has a zoned layout (Fig. 4). The assembly zones are arranged to minimise interference between electricians, plumbers and mechanics. The electrical zone is located in the tractor area of the vehicle, where most electrical work is carried out. The hydraulic zone is located next to the working system, where most of the components of the mining truck's hydraulic system are located. The mechanical zone is located on the opposite side of the machine along the entire assembly station.

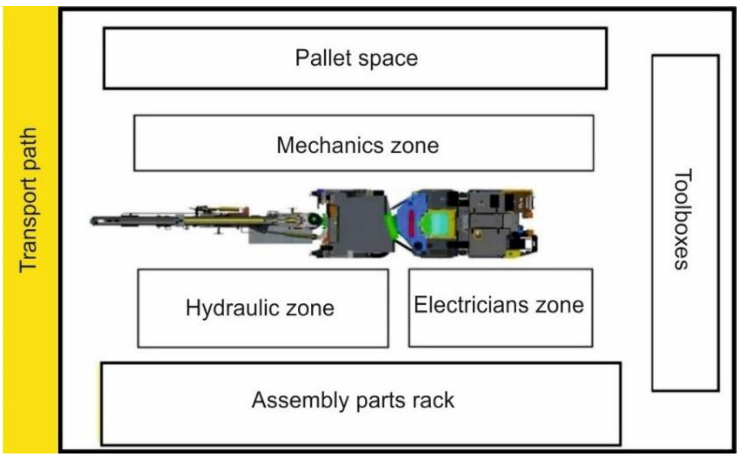

Fig. 4. Diagram of the assembly station after introducing the assembly zones

Toolboxes with specialised power tools and shelving for materials and parts have been installed at the workstation. In addition, the assembly workstations are equipped with mobile trolleys with Kanban-type containers for fasteners. Each trolley with a set of containers is located in its respective assembly area and can be moved to another location if required. The plumber's trolley is equipped with hydraulic connectors, the electrician's with cable glands and the mechanic's with bolts, nuts and washers.

Measurement results after implementing changes

To verify the improvements made, the effectiveness of the time spent assembling the machine was tested again. The test results are presented in the form of graphs in Figures 5 and 6. The percentage of time spent on planned activities is 63.83%. The values for tangible extra time have decreased to 9.56% compared to the previous state. The rate of lost time has also decreased and is now 20.69%.

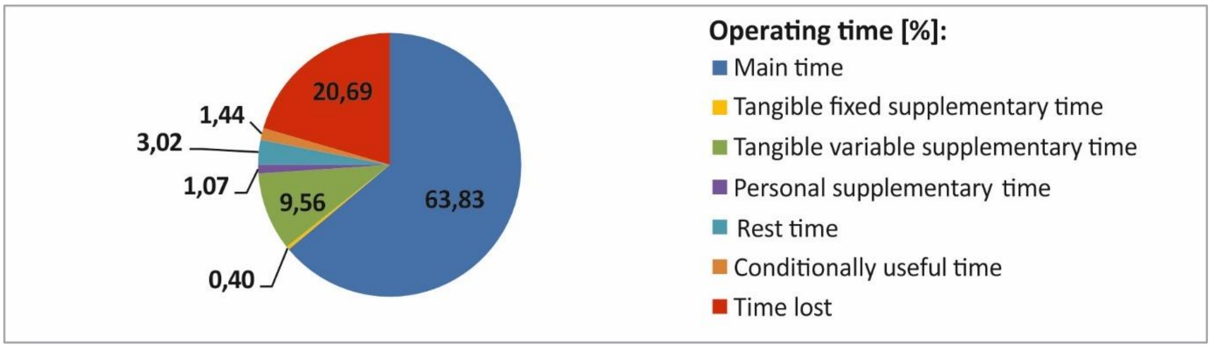

Fig. 5. Structure of working time use by type of time after implementation of changes

The structure of the use of fitters' working time in the main time area increased from 41% and 43% to 66% and 61%.

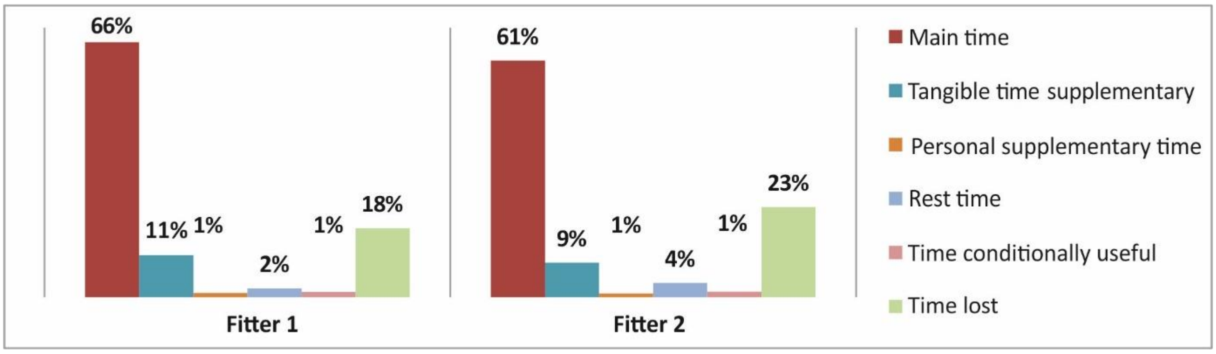

Fig. 6. Structure of the use of fitters' working time after changes in the process

Conclusion

In the assembly process of the Face Master 1.7 K machine, a significant improvement in master time utilisation is noticeable. Measurements showed a 22% increase in the rate of time used to complete tasks. The delivery of the finished cab and the reduction in wasted time to 20.7% allowed more work to be carried out in the tractor area, the work platform and the complete working system to be assembled. As a result, the level of efficiency in the use of prime time increased to almost 64%.

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A NOTE ON MONOTONICITY OF FUNCTIONS

Anton HOVANA – Gabriela IŽARÍKOVÁ

Abstract: Considering real differentiable functions f and g on an interval for which the expressions $r = \frac{f}{g}$ and $\rho = \frac{f'}{g'}$ have sense. Under certain conditions, the classical l´Hospital rule describes a relationship between a limit of function r and the limit of function ρ at a point of the considered interval. This motivated us to focus on the relationship between a monotonicity of considered functions. We have provided that this relationship requires additional condition.
Keywords: monotonicity of function, ratio of functions, derivative of function, limit of function

Introduction

A ratio (in Mathematics) often indicates a relationship between two numbers (indicating, for example, a number of people, units or objects) and it is expressed as a fraction containing these two numbers. The ratios can change in time, therefore they can be considered as the fraction $r = \frac{f}{g}$ where f and g are real functions. From mathematical point of view, there is interesting to understand a variability of such the ratio r. Under normal circumstances, a rate of change (i.e., a derivative) f' and g' can be expressed more easily than f and g, thus the variability of the rate of change the ratio $\rho = \frac{f'}{g'}$ can be determined more easily than the ratio r. In that case, one can see an analogy with the l´Hospital rule for computing special types of limits. Let f and g be differentiable functions, g and g' be non-zero functions on an interval (a, b) that do not change a sign. Then the functions r and ρ are well defined on (a, b) while a and b can be finite or infinite. Then the classical l´Hospital rule for limits says that if for $x_0 \in (a, b)$ there is $\lim_{x\to x_0} f(x) = \lim_{x\to x_0} g(x) = 0$ (or both are infinity), then $\lim_{x\to x_0} r(x) = \lim_{x\to x_0} \rho(x)$ when the limit on right-hand side exists. Our aim is to provide the analogy of the rule in the case of a monotonicity of the function r with respect to the monotonicity of the function ρ. Three groups of mathematicians solved this problem, so we collect their results supported by examples and contraexamples, add our observations and formulate theorems with their proofs. We assume that reader has basic knowledge in mathematical terminology about functions, i.e., the monotonicity, limit and derivative, so we omit definitions.

Main result

In the first year of study at university, a student learns that if a function f is continuous on $[a, b]$ and its derivative is positive (negative) on (a, b), then f is increasing (decreasing) on $[a, b]$. Application of this theorem is easy when working with standard functions. A situation is quite complicated when determining the monotonicity of the ratio of two arbitrary functions. Fortunately, in the available literature there exist several papers where authors focused on that problem. One of the first known result can be found in [2] as follows.

Theorem 1: *Let* $f, g: (0, \infty) \to (0, \infty)$ *be integrable functions. If* r *is non-increasing function, then* $I(x) = \frac{\int_0^x f(t)dt}{\int_0^x g(t)dt}$ *is non-increasing function.*

Remark 1: The statement is still valid when considering functions $f, g: (a, b) \to (0, \infty)$, where $-\infty \leq a < b \leq \infty$.

Considering non-negative integrable functions $f(x) = -\frac{1}{x}$ and $g(x) = \sqrt{-x}$ on $M = [-1,0)$, then $r(x) = -\frac{1}{x\sqrt{-x}}$ is increasing on M, but $I(x) = \frac{\int_{-1}^{x} f(t)\,dt}{\int_{-1}^{x} g(t)dt} = \frac{-\ln(-x)}{\frac{2}{3}x\sqrt{-x}-\frac{2}{3}}$ is decreasing on M. Indeed, for all $x \in M$ we have $I'(x) = \frac{-\frac{2}{3}\sqrt{-x}+\frac{2}{3x}+\sqrt{-x}\ln(-x)}{(x\sqrt{-x}-1)^2}$ and

$$I'(x) = 0 \Leftrightarrow -\frac{2}{3}\sqrt{-x} + \frac{2}{3x} + \sqrt{-x}\ln(-x) = 0 \Leftrightarrow x = -1$$

while for all $x \in M$ there is $I'(x) < 0$. This example demonstrates that it is not possible to replace the assumption „non-increasing“ of the function r by „non-decreasing“. Moreover, we have shown that this condition is just sufficient.

Later on, independently on the previous result, there had been proven more general assertion, see [1].

Theorem 2: *Let $-\infty < a < b < \infty$ and $f, g: [a, b) \to \mathbb{R}$ be differentiable functions such that for all $x \in (a, b)$ there is $g'(x) \neq 0$. If ρ is non-decreasing (non-increasing) function on (a, b), then $h(x) = (f(x) - f(a))/(g(x) - g(a))$ is non-decreasing (non-increasing) function on (a, b).*

Remark 2: One can see that Theorem 1 is a special case of Theorem 2. Indeed, taking $F(x) = \int_0^x f(t)dt$ and $G(x) = \int_0^x g(t)dt$ then for all $x \in (0, \infty)$ we have $F'(x) = f(x)$ and $G'(x) = g(x)$. If the function $r = \frac{f}{g} = \frac{F'}{G'}$ is non-increasing on $(0, \infty)$, then the function $I(x) = (F(x) - F(0))/(G(x) - G(0)) = (F/G)(x)$ is non-increasing. But these theorems cannot be compared in general as it is shown by the following examples.

Taking functions $f(x) = e^{-x}$ and $g(x) = 2\sqrt{x}$ on $M = (0, \infty)$. Then function $r(x) = \frac{1}{2\sqrt{x}e^x}$ is decreasing and by Theorem 1 $I(x) = \frac{3}{4}\frac{1-e^{-x}}{\sqrt{x^3}}$ is decreasing on M. But $\rho(x) = -e^{-x}\sqrt{x}$ is not monotone on M, because

$$\rho'(x) = \frac{e^{-x}(2x-1)}{2\sqrt{x}} = 0 \Leftrightarrow e^{-x}(2x-1) = 0 \Leftrightarrow 2x - 1 = 0 \Leftrightarrow x = \frac{1}{2}$$

and for $x \in \left(0, \frac{1}{2}\right)$ there is $\rho'(x) < 0$ and ρ is decreasing on $\left(0, \frac{1}{2}\right)$ while for $x \in \left(\frac{1}{2}, \infty\right)$ there is $\rho'(x) > 0$ and ρ is increasing on $\left(\frac{1}{2}, \infty\right)$.

Considering $f(x) = \ln(x + \sqrt{x^2 + 1})$ and $g(x) = -\ln x$ on $[1,2)$. Then $\rho(x) = -\frac{x}{\sqrt{x^2+1}}$ is decreasing on $(1,2)$ and by Theorem 2 $h(x) = -\frac{\ln\frac{x+\sqrt{x^2+1}}{1+\sqrt{2}}}{\ln x}$ is decreasing on $(1,2)$ as well. But Theorem 1 is useless because the function g is negative and $r(x) = -\frac{\ln(x+\sqrt{x^2+1})}{\ln x}$ is increasing on $(1,2)$.

Forthcoming example demonstrates that existence of derivative at a point a is the sufficient condition for validity of Theorem 2. Let $f(x) = x$ and $g(x) = \arcsin x$ on $M = [-1,0)$. Then $\rho(x) = \sqrt{1 - x^2}$ and $h(x) = \frac{x+1}{\arcsin x + \frac{\pi}{2}}$ are nondecreasing on $(-1,0)$ but the function g is not differentiable at -1.

Remark 3: The condition of differentiability of functions f and g at the point a can be weekened by existence of one-sided limits at that point, i.e., $A = \lim_{x \to a^+} f(x)$ and $B = \lim_{x \to a^+} g(x)$. By similarity to Theorem 2, we can prove the following statement.

Corollary 1: *Let* $-\infty < a < b < \infty$ *and* $f, g: (a, b] \to \mathbb{R}$ *be differentiable functions such that for all* $x \in (a, b)$ *there is* $g'(x) \neq 0$. *If* ρ *is non-decreasing (non-increasing) function on* (a, b), *then* $k(x) = (f(x) - f(b))/(g(x) - g(b))$ *is non-decreasing (non-increasing) function on* (a, b).

Independently on the previous results, I. Pinelis elaborated the theory of monotonicity r based on monotonicity ρ. The next statement is similar to the classical l'Hospital rule, see [3].

Theorem 3: *Let* $-\infty < a < b < \infty$ *and functions* f, g *be continuous on* $[a, b]$ *and differentiable on* (a, b) *such that* $f(a) = g(a) = 0$ *or* $f(b) = g(b) = 0$. *If for all* $x \in (a, b)$ *there is* $g'(x) > 0$ *or* $g'(x) < 0$ *and* ρ *is non-decreasing (non-increasing) on* (a, b), *then* r *is non-decreasing (non-increasing) function on* (a, b).

Remark 4: Because of the condition on function values at the point a or b, this rule seems to the l´Hospital rule for computing limit of a type $0/0$. The natural question is whether the similar assertion holds when obtaining ∞/∞. Let $f(x) = \frac{1}{2}\ln\frac{1+x}{1-x}$ and $g(x) = \frac{1}{1-x}$ on $[0,1)$. Then $\lim_{x\to 1^-} r(x)$ is the limit of the type ∞/∞, but the function r is not monotone on $[0,1)$ because $r(0) = 0 = \lim_{x\to 1^-} r(x)$ while $\rho(x) = \frac{1-x}{1+x}$ in non-increasing on $[0,1)$.

Below, we show a usage of the previous rule when determining monotonicity of the ratio of two functions without tools of a differential calculus (stationary points, local extrema, etc.). It is worth mentioning that the rule can be applied several times in row under satisfying assumptions as the l´Hospital rule for computing limits.

Example: We determine the monotonicity of $r(x) = x^{-2}(\ln(x+1)^{(x+1)} - x)$ for $x \in (0, \infty)$. Therefore we put $f(x) = (x+1)\ln(x+1) - x$ and $g(x) = x^2$ on $[0, \infty)$ for which $f(0) = g(0) = 0$. Then $\rho(x) = \frac{f'(x)}{g'(x)} = \frac{\ln(x+1)}{2x}, x \in (0, \infty)$ while $g'(x) > 0$ for all $x \in (0, \infty)$. Put $F(x) = \ln(x+1)$ and $G(x) = 2x$. Then $F(0) = G(0) = 0$ and $\vartheta(x) = \frac{F'(x)}{G'(x)} = \frac{1}{2(x+1)}, x \in (0, \infty)$ and $G'(x) > 0$ for $x \in (0, \infty)$. Because the function ϑ is decreasing on $x \in (0, \infty)$, then by Theorem 3 the function ρ is decreasing on $x \in (0, \infty)$ as well. Using the result of the same theorem we obtain that r is decreasing on $x \in (0, \infty)$.

The next example shows the assumption on the function values at one of the endpoints of the interval cannot be omitted. Let $f(x) = \sin x - \frac{1}{2}$ and $g(x) = x$, which are continuous on $\left[0, \frac{\pi}{2}\right]$ and differentiable on $\left(0, \frac{\pi}{2}\right)$. Because of $g(0) = 0 \neq -\frac{1}{2} = f(0)$ and $g\left(\frac{\pi}{2}\right) = \frac{\pi}{2} \neq \frac{1}{2} = f\left(\frac{\pi}{2}\right)$, Theorem 3 is useless. But $\rho(x) = \cos x$ is non-increasing on $\left(0, \frac{\pi}{2}\right)$, so we are interested in monotonicity of the function r. It is easy to see that $r\left(\frac{\pi}{6}\right) = 0$ and by classical approach of differential calculus we get that for all $x \in \left(0, \frac{\pi}{2}\right)$ there is $r'(x) = \frac{2x\cos x - 2\sin x + 1}{x^2}$. Assume, that r is non-increasing, i.e., $r'(x) \leq 0$ for $x \in \left(0, \frac{\pi}{2}\right)$, but $r'\left(\frac{\pi}{6}\right) > 0$, what is a contradiction. In other words, the function r changes monotonicity on $\left(0, \frac{\pi}{2}\right)$.

This example motivated us whether the assumption on the function values at one of the endpoints of the interval can be interchanging by another one to determine the monotonicity of r. We will use the following observation. Considering functions r and ρ on the interval (a, b). Then $r'(x) = \left(\frac{f(x)}{g(x)}\right)' = \frac{f'(x)g(x) - f(x)g'(x)}{g^2(x)} = \frac{\rho(x) - r(x)}{g(x)/g'(x)}, x \in (a, b)$. Assuming that $g(x)g'(x) < 0$ or $g(x)g'(x) > 0$ for all $x \in (a, b)$ we get $\rho(x) - r(x) = r'(x)\frac{g(x)}{g'(x)}$ and consequently $(\rho(x) - r(x))g'(x)g(x) = r'(x)g^2(x)$. Thus the sign of r' depends on the sign of $\rho - r$. Therefore, it is natural to ask about a behavior of the function $H(x) = g(x)r'(x)h(x), x \in (a,b)$, where $h = |g/g'|$. Then we get the statement.

Theorem 4: *Let f and g be differentiable functions on (a,b) and for all $x \in (a,b)$ $g'(x) < 0$ or $g'(x) > 0$.*

a) *If for all $x \in (a,b)$ there is $g(x)g'(x) > 0$ and ρ is non-decreasing (non-increasing) on (a,b), then function H is non-decreasing (non-increasing) on (a,b).*
b) *If for all $x \in (a,b)$ there is $g(x)g'(x) < 0$ and ρ is non-decreasing (non-increasing) on (a,b), then function H is non-increasing (non-decreasing) on (a,b).*

Proof. a) Fix arbitrary $x \in (a,b)$ and consider a function $\alpha_x(y) = f'(x)g(y) - g'(x)f(y), y \in (a,b)$. Then for each $y \in (a,b)$ we obtain $\alpha'_x(y) = f'(x)g'(y) - f'(y)g'(x) = g'(x)g'(y)[\rho(x) - \rho(y)]$. When ρ is non-decreasing (non-increasing) on (a,b), then α'_x is non-negative (non-positive) on the interval (a,x) and non-positive (non-negative) on the interval (x,b). Without lost on generality we assume $a < y < x < b$. Then $g^2(x)r'(x) = \alpha_x(x) = [\alpha_x(x) - \alpha_x(y)] + \alpha_x(y)$. Using the assumption $g(x)g'(x) > 0$ we obtain

$$\alpha_x(y) = g'(x)g(y)[\rho(x) - r(y)] = g'(x)g(y)[\rho(x) - \rho(y)] + \frac{g'(x)}{g'(y)}\alpha_y(y)$$
$$= g'(x)g(y)[\rho(x) - \rho(y)] + \frac{|g'(x)|}{|g'(y)|}\alpha_y(y)$$
$$= g'(x)g(y)[\rho(x) - \rho(y)] + |g'(x)|H(y).$$

Substituting a variable y by the variable x we get $\alpha_x(x) = |g'(x)|H(x)$ and

$$\alpha_x(x) - \alpha_x(y) = |g'(x)|\big(H(x) - H(y)\big) - g'(x)g(y)[\rho(x) - \rho(y)],$$

from which it is possible to obtain a substraction

$$H(x) - H(y) = \frac{1}{|g'(x)|}\Big(\big(\alpha_x(x) - \alpha_x(y)\big) + g'(x)g(y)[\rho(x) - \rho(y)]\Big),$$

which is non-negative or non-positive on (a,b) when ρ is non-decreasing or non-increasing on (a,b), respectively. Second part of statement is analogous taking functions $F(x) = f(a + b - x)$ and $G(x) = g(a + b - x)$ on (a,b).

When returning to the functions stated in Remark 4 that demonstrated useless of Theorem 3, one can see that $g(x)g'(x) = \frac{1}{1-x}\frac{1}{(1-x)^2} > 0$ for $x \in (0,1)$ and ρ is non-increasing on $(0,1)$. Then $H(x) = g(x)r'(x)h(x) = r'(x) = \frac{1}{1+x} - \frac{1}{2}\ln\frac{1+x}{1-x}$ is non-increasing on $(0,1)$.

Note that under the assumption of Theorem 4 the limits of the function H at the endpoins of interval (a,b) are finite which allow us to interchanging assumption $f(a) = g(a) = 0$ or $f(b) = g(b) = 0$ in Theorem 3.

Theorem 5: *Let f and g be differentiable functions on (a,b) and for each $x \in (a,b)$ $g'(x) < 0$ or $g'(x) > 0$. If for all $x \in (a,b)$ there is $g(x)g'(x) > 0$, function ρ is non-decreasing on (a,b) and $\lim_{x\to a^+} H(x) \geq 0$, then function r is non-decreasing on (a,b).*

Proof. Fix arbitrary $x \in (a,b)$ and consider the function α_x as in the proof of Theorem 4. Such function is continuous and non-decreasing on $(a,x]$. Fix $c_0 \in (a,x)$. Then for each $c \in (a,c_0]$ we have

$$f(x)\big(g(x) - g(c)\big) - g'(x)\big(f(x) - f(c)\big) = \alpha_x(x) - \alpha_c(c) \geq \varepsilon > 0, \qquad (1)$$

where $\varepsilon = \alpha_x(x) - \alpha_x(c_0)$. Furthermore,

$$g^2(x)r'(x) = f'(x)g(x) - f(x)g'(x)$$
$$= f'(x)\big(g(x) - g(c)\big) - g'(x)\big(f(x) - f(c)\big) + \big(\rho(x) - \rho(c)\big)g(c)g'(x) + H(c)|g'(x)| \qquad (2)$$

Where g' is non-zero function which does not change the sign on (a, b), so $\rho(c) = |\rho(c)|$. On one side, from the right-hand side of equation (2) it follows:

i. With respect to equation (1), the first term is not less than fixed $\varepsilon > 0$, where $\varepsilon = \alpha_x(x) - \alpha_x(c_0)$ for each $c \in (a, c_0]$;
ii. Second term in non-negative for each $c \in (a, c_0]$ because ρ is non-decreasing on (a, b) and $g(c)\, g'(x) > 0$ what follows from $g(x)g'(x) > 0$ and g' does not change the sign on (a, b);
iii. The limit of the third term for $x \to a^+$is non-negative because of $\lim_{c \to a^+} H(c) \geq 0$.

On the other side, the left-hand side of equation (2) does not depend on c. When taking $c \to a^+$ we get $r'(x) \geq \varepsilon > 0$, for all $x \in (a, b)$, and therefore function r is non-decreasing on (a, b). From the previous proof of the theorem, we directly deduce the following.

Corollary 2: *Let f and g be differentiable functions on (a, b) and for each $x \in (a, b)$ $g'(x) < 0$ or $g'(x) > 0$.*

a) *If for all $x \in (a, b)$ there is $g(x)g'(x) > 0$, function ρ is non-decreasing on (a, b) and $\lim_{x \to a^+} H(x) \geq 0$, then function r is non-decreasing on (a, b).*
b) *If for all $x \in (a, b)$ there is $g(x)g'(x) > 0$, function ρ is non-increasing on (a, b) and $\lim_{x \to a^+} H(x) \leq 0$, then function r is non-increasing on (a, b).*
c) *If for all $x \in (a, b)$ there is $g(x)g'(x) < 0$, function ρ is non-decreasing on (a, b) and $\lim_{x \to b^-} H(x) \leq 0$, then function r is non-increasing on (a, b).*
d) *If for all $x \in (a, b)$ there is $g(x)g'(x) < 0$, function ρ is non-decreasing on (a, b) and $\lim_{x \to b^-} H(x) \geq 0$, then function r is non-decreasing on (a, b).*

Proof. Part a) is the statement of Theorem 5. Part b) can be proven similarly to part a) when taking function $F = -f$. To prove parts c) and d) it is enough to put functions $F(x) = f(a + b - x)$ and $G(x) = g(a + b - x)$ for all $x \in (a, b)$ in parts a) and b).

Remark 5: Based on the result of Theorem 4, one can see that information about the monotonicity of functions ρ and H is the same. Indeed, when we know sign of gg' then the monotonicity of function H is the same as the monotonicity of ρ and vice versa, i.e., when we determine the monotonicity of H and the sign of gg', then we can provide an answer to the monotonicity of ρ.

Taking functions $f(x) = \frac{1}{x} - \ln x$ and $g(x) = \frac{1}{x}$ on $M = \left(0, \frac{1}{e}\right)$. Then the functions $r(x) = 1 - x \ln x$ and $\rho(x) = 1 + x$ are non-decreasing on M. Then for all $x \in M$ we have $g(x)g'(x) = \frac{1}{x}\frac{-1}{x^2} < 0$ and $H(x) = g(x)r'(x)h(x) = r'(x) = -(1 + \ln x) > 0$ while $\lim_{x \to \frac{1}{e}^-} H(x) = 0$. By Corollary 2d) function r is non-decreasing on M.

Considering functions $f(x) = \frac{1}{x}$ and $g(x) = \frac{1}{\sin x}$ on $\left(0, \frac{\pi}{2}\right)$. Then $\rho(x) = \frac{\sin^2 x}{x^2 \cos x}$ is non-decreasing on $\left(0, \frac{\pi}{2}\right)$ and for all $x \in \left(0, \frac{\pi}{2}\right)$ there is $g(x)g'(x) = -\frac{\cos x}{\sin^3 x} < 0$ and $H(x) = g(x)r'(x)h(x) = \frac{\frac{1}{\sin x}}{\frac{\cos x}{\sin^2 x}} \frac{1}{\sin x} \frac{x \cos x - \sin x}{x^2} = \frac{x - \tan x}{x^2} < 0$. Because of $\lim_{x \to \frac{\pi}{2}^-} H(x) = -\infty$ and by Corollary 2c) function $r(x) = \frac{\sin x}{x}$ non-increasing on $\left(0, \frac{\pi}{2}\right)$. We have shown that this rule is also applicable even in the situation when Theorem 3 fails, i.e., when obtaining limit of the type ∞/∞.

In the situation, when $f(x) = \cosh x$ and $g(x) = x$ on $(0, \infty)$, we get that $\rho(x) = \sinh x$ that is increasing on $(0, \infty)$ and $H(x) = x \sinh x - \cosh x$ is increasing on $(0, \infty)$ as well, but

$\lim_{x\to 0^+} H(x) = -1$, so Theorem 5 and Corollary 2 says nothing about the monotonicity of $r(x) = \frac{\cosh x}{x}$. However, $\lim_{x\to 0^+} r(x) = \lim_{x\to\infty} r(x) = \infty$, so function r is not monotone on $(0,\infty)$, so the condition on the value of the limit of function H at the endpoints of interval (a,b) cannot be omitted. The next natural question should be stated whether there exists a weaker (or simpler) condition than $\lim_{x\to a^+} H(x) \geq 0$ in Theorem 5 (and consequently in Corollary 2) under which the statement is true. If the answer on previous problem will be negative, then the next open problem will be if the condition $\lim_{x\to a^+} H(x) \geq 0$ is also necessary one. Other open problem is to look at the rules stated here in discrete versions.

Conclusion

In presented paper we have focused on monotonicity of function $r = \frac{f}{g}$ under monotonicity of function $\rho = \frac{f'}{g'}$, while functions considered therein have sense. This task had been solved by three groups of mathematicians independently. As it turns out when generalizing their results, monotonicity of r depends not only monotonicity of ρ but also on the value of the limit of the function H at endpoints of interval functions f and g are considered on, while $H = gr'h$ and $h = |g/g'|$. Finally, we have formulated some open problems.

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REVIEW OF METHODS FOR INTRODUCING A DIGITAL TWIN IN ONLINE CONTROL AND MONITORING OF THE MANUFACTURING PROCESS

Michal BALOG – Angelina IAKOVETS – Anastasiia NAZIM

Abstract: This article provides a comprehensive review of various methods and approaches for implementing a digital twin in the online control and monitoring of the production process. The modern trends in manufacturing dictates using of online technologies in all activities if the enterprise. Digital twin is one of the tools that provides inline monitoring and control of any activity, it can be realized by using combination of sensors and software, that gives the relevant information about processes. Proposed research gives the information about key components and characteristics of a digital twin, models and methods of digital twin creating and key activities, that can be digitalized. Highlighted challenges and limitations associated with digital twin implementation will be useful for all enterprises in manufacturing field and can be used as a ground for design own method and model of digital twin implementation.

Keywords: digital twin, control, monitoring, manufacturing.

Introduction

Planning, coordination, management and control of the production process is an integral part of the modern production process. The trends Industry 4.0 [1] and 5.0 [2] dictate the use of smart systems where the tools for ensuring smartness are sensors, camera systems and indicators, that signalize about relevant problems and actual processes. Modern smart systems do not exist without digital environment, that collect, transform, process and storage data about all the processes. The next level of the such type of the software becomes digital twins, that are copy of the small device and big manufacturing systems and enterprises.

The digital era has contributed to the fact that even the smallest manufacturing enterprise uses smart systems, but there are still fewer enterprises that have digital counterparts. In recent years, there has been an opinion that the creation of a digital double is an expensive and long process. The proposed research aims to show that the implementation of a digital twin is not something complicated and expensive.

Implementing a digital twin and any technical change is similar and therefore it is possible to divide it into several stages, which will allow you to consider the place and area of use of the digital twin.

Review of methods for introducing a digital twin

The implementation of the digital twin can take place at different stages:

- design or modelling of production. At this stage, a digital model of a component of the production system or the entire system is created before it is physically integrated into real processes. After the real system meets the digital requirements, the systems are parried so that the real process is displayed in its digital version.

The benefits of this stage are:

- reducing the costs associated with the purchase of equipment,
- reduction of costs associated with the adjustment or readjustment of production,

- reduction of time associated with the planning of production processes,
- regulation of production processes and calculation of production time.

– modernization or improvement of existing systems or processes. At this stage, a digital twin of the existing process is created in which the most suitable element or the arrangement of existing elements is selected to achieve the best result.

Both stages involve the creation of a virtual model that will be linked to the real one. The virtual model can be in 3D or PFT form [3].

– Controlling and monitoring of manufacturing process. This stage is an in-between stage because can be used during testing on a new systems or during improvement of existing systems. The advantage of this method based on constant collecting and processing data from devices to create database or norms for manufacturing process to achieve the best result. During control of the manufacturing process, it becomes possible to avoid problems related to the decrease in product quality [3], which are caused by untimely replaced components of processing knives, etc. Controlling, in turn, helps to build a management system, for which qualitative and quantitative indicators of processes and objects are fixed. As a rule, the determination of indicators begins with the monitoring of information about internal and external factors influencing the quality of production operations. When determining quantitative indicators, not only a system of diagnostic indicators is developed, but their value and priorities are determined.

No matter what stage of digital twin implementing was chosen, there are two main ways how to link digital model with real object or system:

- By manual programming of individual components and their further connection at the level of the enterprise information system. This is a labor-intensive process, as it requires human intervention and manual readjustment of the system according to production requirements.
- the second way is to use artificial intelligence, which will learn and adapt to the requirements of the system. This process is less cumbersome as the AI adapts itself [4], [3].

There are several methods of implementing a digital twin in the online control and monitoring of the production process. Here are a few common approaches:

1. Data Integration: Collecting data from various sources such as sensors, machines, and other production equipment, and integrating it into a digital twin platform. This allows for real-time monitoring and control of the production process.
2. Simulation and Modeling: Creating a virtual model of the production process that mirrors the physical system. This model can be used to simulate different scenarios, optimize processes, and make predictions about system behavior.
3. Machine Learning and AI: Using machine learning algorithms and artificial intelligence techniques to analyze data from the production process and make intelligent decisions. This can include predicting equipment failures, optimizing production schedules, and identifying process improvements.
4. IoT and Connectivity: Leveraging the Internet of Things (IoT) to connect devices and equipment in the production process. This allows for real-time data collection, remote monitoring, and control of the production process.
5. Visualization and Analytics: Using visualization tools and analytics software to present data from the production process in a user-friendly format. This enables operators and managers to easily understand and analyze the data, identify trends, and make informed decisions.

6. Cloud Computing: Storing and processing data related to the production process in the cloud. This allows for easy access, scalability, and collaboration across different locations and stakeholders. [5]

It's important to note that the implementation of a digital twin is closely linked with IoT (internet of things), because non possible without using sensors and CPU (control point unit) integrated into information system of enterprise. The main idea is to constantly receive data from physical object to digital copy of it.

During integration of digital twin requires processing of a huge value of data, in other words Big Data processing [6]. Not all value of data is necessary for daily manufacturing process, but some of them can be useful for strategic planning and long-time planning of manufacturing processes.

The digital twin system not only provides ability of control and monitoring of manufacturing process, but requires control due its functionality (see Fig.1).

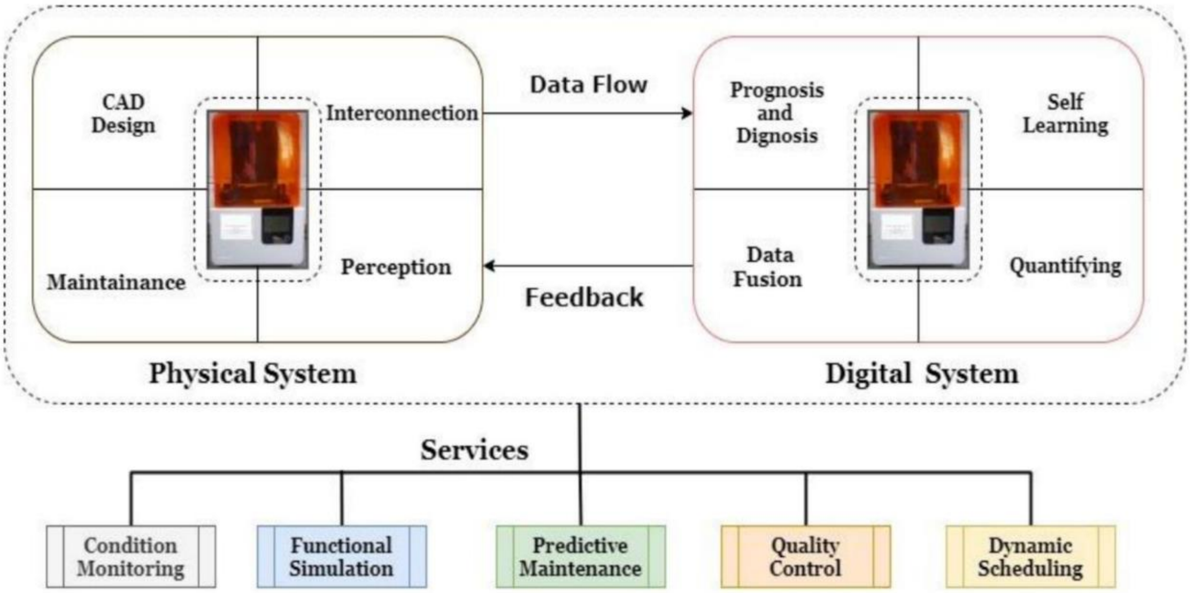

Fig. 10 Digital Twin architecture for Industry 4.0 [5]

In another words, digital twin becomes a system of physical object or system and its digital copy, that mirrors all the processes in real time [7]. The enterprises should to provide constant control of system functionality by own employees and HW and SW systems or to buy such a service from external one firm.

The complexity of the digital twin system [8] opens up both positive and negative perspectives for enterprises, which should be weighed before integrating such systems into their production activities.

Positive prospects include:

- increasing the flexibility of the enterprise to internal and external factors of production,
- reduction of costs associated with modernization or reorganization of production,
- improvement of product quality due to constant quality control of the production process,

- reduction of equipment maintenance costs,
- remote control of the production process,
- a clear picture of the current state of the enterprise and the prospects for better planning providing of a smart factory [9, 10]

Negative factors include:

- the need to employ new, more skilled personnel,
- the occurrence of production downtimes associated with upgrading the qualifications of existing personnel and technical reconfiguration of production and non-production processes,
- theft of enterprise data,
- costs related to equipment service,
- inability to independently provide timely service of system components and their reconfiguration.

The digital twin system has five layers, where each lay should be serviced and constantly controlled (see Fig.2)

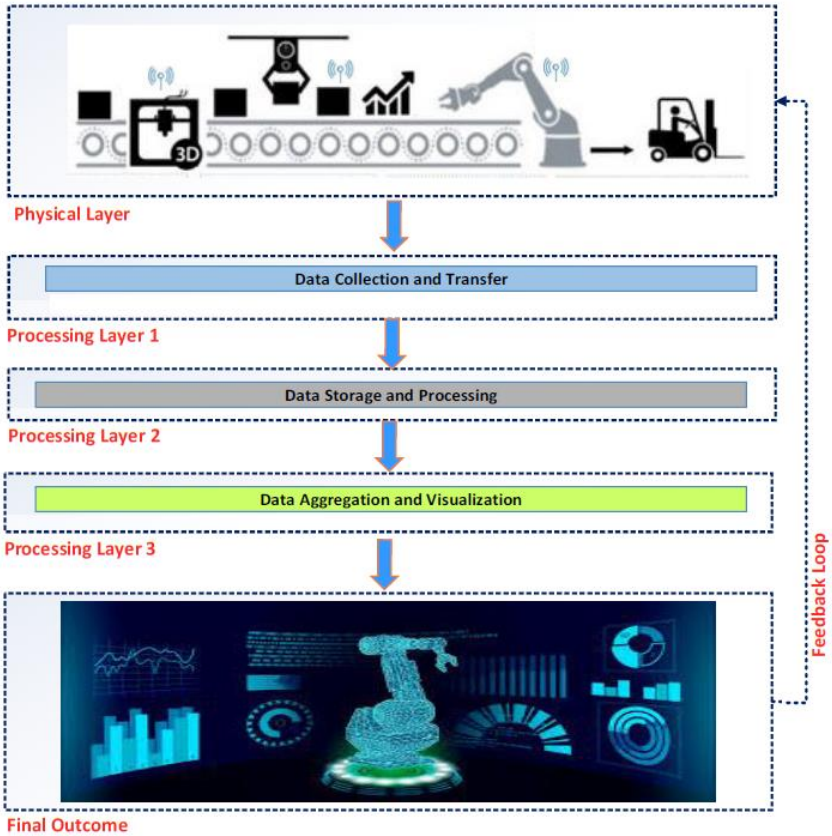

Fig. 11 Digital twin system in manufacturing enterprise [5]

Conclusion

Summarizing the positive and negative aspects of the implementation of digital twins, it can be said that they can nevertheless become a strong flexibility tool for SMEs. Currently, flexibility to customer needs is key, and therefore investing in this type of technology can open the prospects of obtaining new customers, a new market and, in general, the prospect of receiving orders and collaborations with large business leaders in the manufacturing sector.

The integration of digital twins with other technologies such as the Internet of Things (IoT), artificial intelligence (AI) and cloud computing opens up further prospects for enterprises, namely the continuous improvement of production and their competitiveness.

The combination of these technologies allows for real-time data collection, analysis and decision-making, allowing manufacturers to optimize their processes and respond quickly to changes that are now occurring almost instantaneously.

When implementing digital twins, one should weigh and evaluate their strengths in advance so that the shortcomings mentioned in the article are eliminated at the stage of implementation planning. To assess its strengths, the enterprise can choose any of the methods used to assess the feasibility of implementing Industry 4.0 components. [11] For example: TOE (technology–organization–environment), multiple-criteria decision-making approach (MCDM), influence network relations digraph (INRD) or with accordance to DEMATEL method [12].

Additionally, as the article highlights, it is important for businesses to focus their attention on the importance of data governance and cybersecurity. Sound data management and security measures are essential to protect sensitive information and ensure the integrity and reliability of the digital doppelganger.

In general, a review of the methods of implementing the digital double in online control and monitoring of the manufacturing process has shed light on the potential benefits and challenges associated with this technology. It provides a valuable resource for researchers, engineers, and decision makers in the manufacturing industry who are interested in applying digital twins to improve their operations.

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EXPANDING THE PRODUCTION CAPACITY OF THE PRODUCTION HALL AND VERIFYING ITS OUTPUTS WITH THE HELP OF A SIMULATION MODEL

Marek KLIMENT – Jozef TROJAN – Dariusz MICHALSKI – Milan FIĽO

Abstract: The contribution is oriented to the field of applicability of simulation software in the field of real conditions of already existing production. The company is planning a significant expansion of production and would like to verify the effects of this type of innovation before physically interfering with the established existing production. In order to create a reliable simulation model, a high-quality mapping of the current production process and the collection of information that impacts this process is necessary. Subsequently, it is necessary to make a digital model of current production and gradually expand it with new factors that the company plans to implement in the future.
Keywords: Production expansion, innovation, planning, simulation

Introduction

The paper evaluates and compares several variants within the extension of the production process. It is necessary to realize that the expansion of the main phase of the production process, which consists of an increase in the volume of production, which is achieved by doubling the number of production lines, will in no small way affect the supply of this production. It will also affect the processing of finished products after the actual production of the products has been completed. It is therefore necessary to evaluate several options for optimizing the supply of production lines. It is also necessary to ensure sufficient packaging and palletizing of finished products before export to the shipping warehouse. We will use simulation software to verify individual designs and variants, which in a digital environment can very easily implement the properties of all factors into a digital model of existing production, as well as evaluate the impact of all changes made within the production process.

1. Description of existing production

The current state of the production hall consists of 8 production lines that produce a wide range of products that make up the production program of the company. These lines are currently supplied with the help of a forklift truck. Before the start and at the beginning of each shift, the input warehouse workers pick the required amount of inputs, and the forklift operator transports these inputs to all the lines. Workers on the production lines gradually process the relevant production inputs. After the completion of all production operations on the production lines, the products are gradually packed and then placed in the prescribed quantity on pallets. Outputs are packed in the following way: 35% of all finished products are placed directly on pallets and then stretched, 65% of products are first packed depending on the type of output into smaller packages and these are then placed on a pallet and then also stretched (Fig. 1).

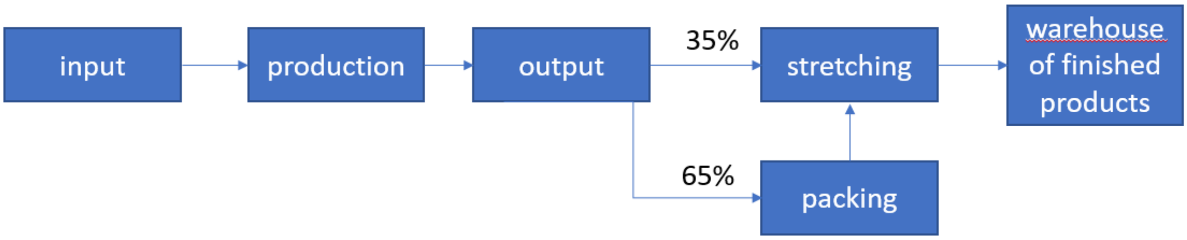

Fig. 6 Scheme of the initial production process

Subsequently, the products on pallets are moved to the dispatch warehouse. One packer is currently used for packaging for all 8 lines.

2. Expansion of production capacity and the number of production lines

The production plant plans to increase the production of its products by more than 100%. in order to achieve this result, it plans to increase the number of production lines from the original 8 through gradual investments and expansion of production to 16 production lines. It is therefore planned to invest in the purchase of 8 new production equipment in the main production phase of the plant. The 4 new production lines should be identical to the equipment used at the same time. These are production lines that gradually process production inputs and create from them paper and ecologically degradable food bags of various types and sizes. Each of the simultaneously used devices as well as half of the planned machines work as a single track line. The other 4 machines, which are planned as an investment, should work as two-track lines that process a larger volume of input and thus produce significantly more outputs at the same time.

The role of the simulation in the planning process was to implement all new lines into current production, taking into account all available data on current equipment as well as new equipment and to evaluate further impacts of such expansion of production on other phases of the production process.

The first impact was the solution to the supply of expanded production with inputs. The current method of importing inputs with the help of one forklift truck would be insufficient and this truck would not have time to ensure enough inputs for the entire production process. Increasing the number of trucks supplying production would not be an optimal solution, as it would require rebuilding the input warehouse. The dispositional change of the input warehouse is not part of the production capacity increase plan. It was necessary to verify several variants of how it is possible to deliver the inputs to the production lines in the required time and volume. Several variants were verified by simulation:

- Supply using conveyors,
- Supplying with the help of a train and several wagons to ensure sufficient inputs,
- Supplying with the help of an AGV truck, which would supply the input intermediate warehouses at the production lines.

With the optimal setting of the properties in all variants, it would be possible to solve the production supply. Each solution requires its own layout and handling space and consideration of additional auxiliary operations, such as loading, and unloading of inputs as well as consideration of their diversity and size. Also, every solution requires taking into account the optimal frequency of supply, so that there are not few inputs, which would hamper production, but on the contrary, there are not too many, which would result in the blocking of a large space in the area of input intermediate warehouses.

3. Proposal of methods of handling and packaging of outputs after completion of the production phase of the process

As already mentioned, the production process does not end with the completion of the finished products, it is necessary to pack them in the necessary quantity and according to the specified requirements and deliver them to the dispatch warehouse. With a significant increase in production, the current package of products will no longer be sufficient for packaging all products. Also, the equipment for stretching pallets does not have time to stretch the necessary amount of finished pallets. For this reason, several variants and methods of transportation of finished products in the packaging process were evaluated. Evaluated variants:

1. 2 packaging machines + 2 stretching machines
2. 3 packaging machines + 3 stretching machines
3. 3 packaging machines + 2 stretching machines
4. 4 packaging machines + 2 stretching machines
5. 2 packaging machines + palletizing machine + 3 stretching machines with a 35:65 distribution of production
6. 2 packaging machines + palletizing machine + 2 stretching machines
7. 2 packaging machines + palletizing machine + 3 stretching machines in the 45:55 distribution of production
8. 3 packing machines + palletizing machine + 2 stretching machines

All the mentioned simulation-verified variants were 35:65% in the distribution of production as stated in part 1. Only in one case did we adjust the distribution of production in the ratio of 45:55% during verification. This adjustment of the distribution ratio of the packaging method of finished products showed that if it were possible to adjust the production ratio in this way, variant no. 7 usable. If the ratio of the packaging method is maintained at the level of 35:65, the most suitable variant no. 8 (Fig. 2).

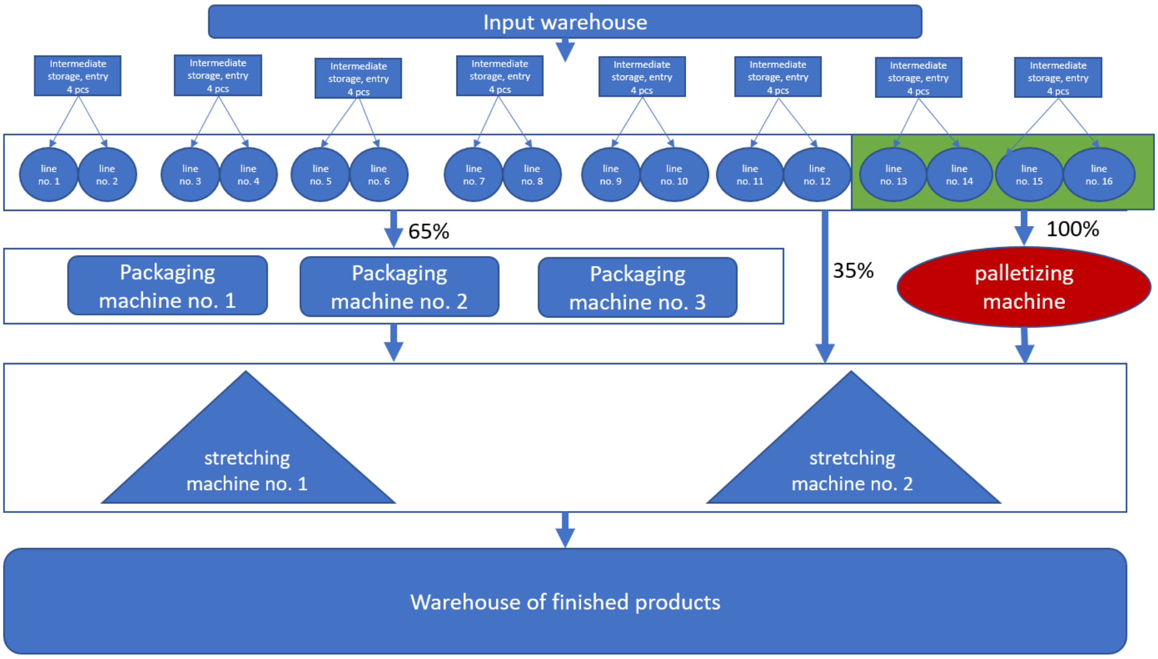

Fig. 7 The most suitable variant of production expansion and its scheme

Conclusion

From the above-mentioned facts, the meaning and justification of simulation software can be clearly seen, whether in expanding existing production processes, or creating and planning new ones. It is also effective to use them for planned minor interventions in processes or for various innovations in production. With the help of simulation, in this particular case, 13 different variants of the form of the production process, including the original state, were created. If the verified changes in production were to be tested physically directly in the production, it would cause a limitation of the operation of the working process and a very large cost would be spent on all the necessary equipment that was digitally verified.

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KEY PERFORMANCE INDICATORS AS A TOOL FOR EVALUATING EFFICIENCY OF PRODUCTION PROCESSES

KĽÚČOVÉ UKAZOVATELE VÝKONNOSTI AKO NÁSTROJ HODNOTENIA EFEKTÍVNOSTI VÝROBNÝCH PROCESOV

Erika SUJOVÁ – Ivan BABIC – Jozef KRILEK

Abstract: The paper deals with the efficiency evaluation of production processes using key indicators in custom manufacturing. Various key process performance indicators relevant to engineering production were identified. Subsequently, the implementation procedure of selected KPIs for process efficiency evaluation was proposed. The proposed algorithm was verified in practice through KPI - internal share of non-conforming products. At the end of the paper, the reasons for not achieving the KPI target values were identified, and measures were proposed to improve the results in terms of modification, diagnosis, and maintenance of problematic equipment.

***Abstrakt**: Článok sa zaoberá hodnotením efektívnosti výrobných procesov pomocou kľúčových ukazovateľov v zákazkovej výrobe. Identifikované boli rôzne kľúčové ukazovatele výkonnosti procesov relevantné pre strojárenskú výrobu. Následne bol navrhnutý postup implementácie vybraných KPI pre hodnotenie efektívnosti procesov. Navrhnutý algoritmus bol overený v praxi prostredníctvom KPI - interného podielu nezhodných výrobkov. V závere príspevku boli identifikované príčiny nedosahovania cieľových hodnôt KPI a navrhnuté opatrenia pre zlepšenie výsledkov z hľadiska úpravy, diagnostiky a údržby problematických zariadení.*

Keywords: key performance indicator (KPI), non-conforming product, diagnostics, maintenance

***Kľúčové slová:** kľúčový ukazovateľ výkonnosti (KPI), nezhodný výrobok, diagnostika, údržba*

Introduction

The current competitive market environment imposes high demands on the maximum performance of manufacturing enterprises. With expanding competition and a highly competitive landscape, the pressure on the performance and efficiency of companies is increasing. Enterprise management recognizes that achieving and gaining a competitive advantage leads through the efficiency and performance of processes. In order to operate efficiently and strengthen market position, it is important to monitor individual activities within the company. Currently, basic financial indicators, which are mostly focused on the past and do not sufficiently reflect the need for improvement in specific areas to achieve the company's priority goals, are no longer sufficient for performance evaluation. Companies aiming to enhance their competitiveness must also focus on other decisive factors for the sustained success of the enterprise. Assessing a wide range of relevant indicators that express the overall performance of processes plays a significant role in today's context. We refer to them as key performance indicators.

Key Performance Indicators (KPIs) are among the most common indicators of process efficiency in today's context. This term refers to indicators, i.e., performance metrics and measures assigned to a process, service, organizational unit, or the entire organization. KPIs express the desired performance by assessing the quality, efficiency, or economy of the evaluated entity. They are used at all levels of organizational management, primarily in strategic management, goal-oriented management, and service management [1].

In the standard STN EN ISO 9004:2010 [2], in chapter 8.3.2, key performance indicators are defined as factors that an organization controls and are critical to its sustained success. These must undergo performance measurement and be identified as key performance indicators (STN EN ISO 9004:2010). KPIs are undoubtedly essential tools for measuring and controlling all processes within an organization. These indicators allow for the identification of whether activities are being carried out effectively and help optimize all involved resources. KPIs must reflect the organization's corporate strategy and competitive factors and should focus on how results are achieved [3, 4]. KPIs must also be meaningful, coherent, goal-driven, and standardized for objective comparison across different organizations [5]. Many published research papers have dealt with defining and identifying the benefits associated with implementing KPIs into business processes [6, 7]. We can state that all authors agree that the most significant contribution of KPIs lies in increasing the efficiency of business processes and improving product quality by introducing measurable production indicators [8, 9].

After reviewing numerous literary sources, it is evident that the implementation of key performance indicators brings many advantages to businesses that decide to adopt them. The following benefits are prioritized: providing transparent goals for employees, enhancing productivity, improving the quality of managerial decision-making processes, making performance evaluations more objective and purposeful, strengthening organizational efficiency, enhancing the quality of services provided, and establishing clear safety metrics [10, 11].

Materials and Methods

The research was conducted in an engineering company specializing in the machining of both metallic and non-metallic components using cutting processes [12]. The products of the analysed company (Figure 1) are utilized in window system mechanisms, the furniture industry, hydraulic units, and primarily in products manufactured by renowned automobile producers, as well as manufacturers of heavy-duty vehicles.

Figure 1 Example of manufactured components [12]

The production involves a wide range of components manufactured mainly through cutting processes, ranging from simple turned parts to intricately machined pieces finished through grinding, threading, rolling, or milling. The primary manufacturing process is CNC machining of both metallic and non-metallic parts. The essence of the production technology is represented by machining centres, CNC lathes predominantly working with bar material, and compact horizontal centres. The products consist of turned and milled components, which can subsequently undergo finishing processes such as grinding, thread rolling, or drilling. The company primarily monitors order-based financial indicators, but it considers it important and necessary to begin tracking indicators that express the overall performance of processes.

The implementation process of KPIs in the analysed company was divided into steps, the fulfilment of which is crucial for the success of the KPI implementation itself. The sequence of carrying out these steps is vital both in the planning phase and during the actual implementation of KPIs into the company's processes.

For the planning of individual steps of KPI implementation into production processes, an algorithm was developed. This algorithm defines the specific steps of introducing KPIs, as well as the assessment of process performance and subsequent actions in case of not achieving the goals:

Step 1. Creation of processes maps.
Step 2. Identification and determination of processes and process owners to be measured.
Step 3. Definition of key performance indicators for the process.
Step 4. Data sources, input measurements for selected KPIs.
Step 5. Analysis and reporting of current process performance.
Step 6. Evaluation of the achievement of process performance goals.
Step 7. Identification of actions for improving process performance.
Step 8. Verification of action implementation, and ongoing data collection and subsequent data analysis.

Based on Step 3, KPIs relevant to the evaluated production were subsequently designed. The identified indicators characterizing product quality include: the number of complaints, plan fulfilment, the number of non-conformities, overall productivity, and production time per unit.

Results and Discussion

For the purposes of our research, we selected the KPI "number of non-conformities" [12]. Specifically, the performance of orders for part A was assessed based on the number of non-conforming pieces over the total duration of the orders during the 16 months of 2022 and 2023. The result is an expression of internal ppm (parts per million) for part A for each individual order (Table 1). The evaluation is always conducted for the production period of a specific order after its completion. The inputs are the number of produced products per order and the number of non-conforming products generated during that specific order. The indicator *INTppm* (1) represents the overall production stability for the duration of a particular order during the evaluated period:

$$INT_{ppm} = \frac{Q_n}{Q_t} \cdot 1000000 \qquad (1)$$

Where:
Q_n – quantity of non-conforming products in the order,
Q_t – total quantity of products manufactured in the given order.

Table 1 Evaluation of order performance for part A using *INTppm* for the evaluated period

Order Number	Order Completion Date	Total Quantity of Produced Part A in the Order (*Qt*)	Quantity of Non-Conforming Part A in the Order (*Qn*)	Internal ppm (*INTppm*)
1	3.1.2022	1536	5	3255
2	27.1. 2022	1536	0	0
3	24.2. 2022	1536	1	651
4	9.3. 2022	2304	2	868
5	21.4.2022	2304	29	12587
6	28.6.2022	2000	3	1500
7	21.7. 2022	2304	22	9549
8	1.8. 2022	2022	14	6076
9	9.9. 2022	2152	12	5576
10	10.10. 2022	2304	5	2170
11	7.11. 2022	890	8	8989
12	19.12. 2022	1536	16	10417
13	13.1. 2023	1152	5	4340
14	15.2. 2023	1920	5	2604
15	22.3. 2023	2304	0	0
16	15.4. 2023	2000	5	2500

In the graph (Fig. 2), the values from the table (Table 1) are visually represented. The graph illustrates a comparative analysis between the quantities of produced pieces per order and the internal ppm per order.

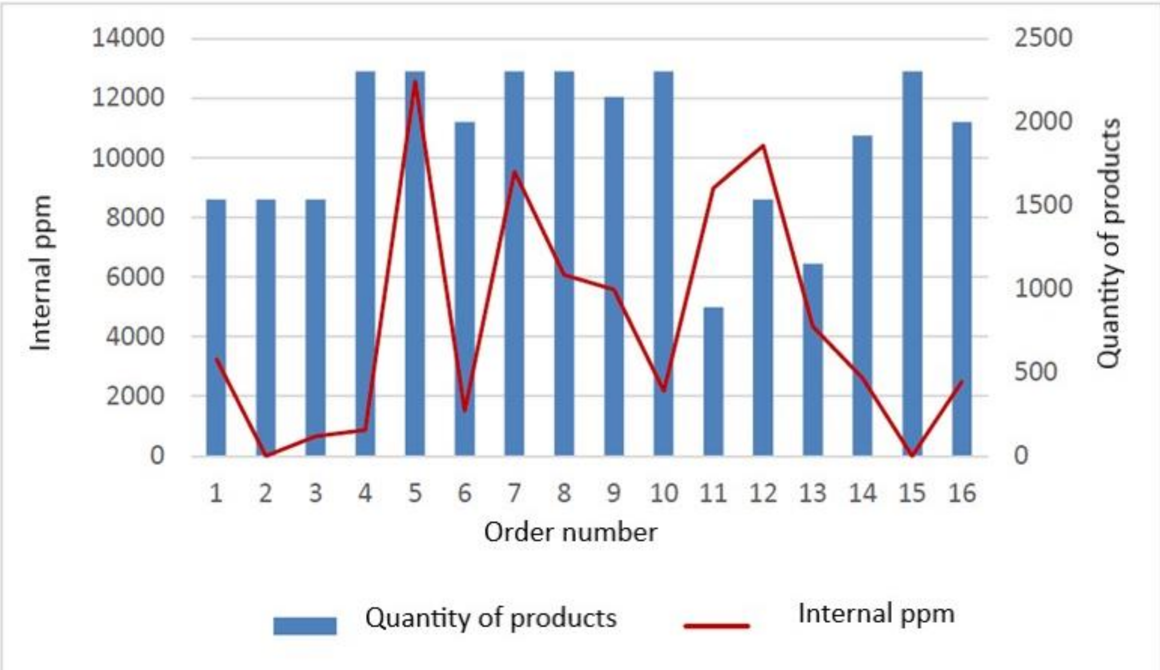

Figure 2 Graphical Evaluation of Order Performance for Part A using internal ppm *INTppm*

When evaluating the results displayed in the graph in Figure 2, it can be observed that the *INTppm* values exhibit a highly fluctuating tendency, reflecting the instability of the assessed process. The target value for the evaluated KPI is the value of the overall internal ppm, which was set as a quality target for the company in 2022 and 2023, with a maximum value of 2000 ppm. Therefore, the target *INTppm* value is to achieve a maximum of 2000 ppm for each evaluated order for part A. The achieved average value for individual part A orders during the monitored period, encompassing 16 initiated and completed orders, was 4443 ppm. This indicates that the company's goals in terms of quality and process performance were not met for the specific part A orders. In the analysed company, each non-conforming part is recorded in the company-wide information system called Dialog. Besides the count of non-conforming products, the system allows for entering a description of the non-conformity and its root cause. Following an analysis of the records in collaboration with production operators, production managers, technologists, and quality department personnel, the following descriptions and causes of non-conforming products were identified:

1. Short piece after turning operation, with the cause stated as "clamping error" in the turning operation.
2. Damaged piece, with the cause indicated as "worn cutting insert, need for replacement of the cutting insert."

To eliminate the occurrence of non-conforming pieces, it was necessary to address the identified causes of non-conformities. Based on an analysis of the causes of non-conformities in the analysed process and feedback from stakeholders regarding the issue, the following actions were agreed upon:

1. Elimination of the cause of improper clamping during turning - The technologist will consider the possibility of modifying the clamping process, adjusting the stop, and re-turning the soft jaws of the chuck. The stop against which the part rests during clamping needs to be adjusted so that the part is supported at multiple points, thereby eliminating the possibility of skewed clamping of the part in the chuck.
2. Removal of the cause of worn cutting inserts and timely replacement of cutting inserts during the turning operation involves appropriate diagnosis of the problem and machine maintenance. Preventing the wear of cutting inserts and the resulting non-conforming parts involves specifying an appropriate replacement interval for the cutting insert. The frequency of cutting insert replacement can be determined based on the guidelines provided by the cutting insert suppliers and verified during subsequent production orders. The process of changing the cutting insert is also critical, and it can prevent the occurrence of the first non-conforming piece by focusing on critical dimensions. In this case, the critical dimension is the overall length of the product, which can be adjusted with a suitable excess and subsequent correction.

Conclusion

The implementation of KPIs in the manufacturing company environment represents a demanding and long-term process. For the successful management of this process, one of the most crucial aspects is the support of top management, supervisors, and, not least, the employees themselves working in positions related to the implemented KPIs. Monitoring KPIs creates a procedure through which an organization identifies and sets operational goals to ensure and enhance process performance. The goal of the research presented in the paper was to propose a procedure for implementing key performance indicators in production processes and to determine the values of the measured indicators.

The identified KPIs were precisely defined for the comprehensibility of all stakeholders, allowing for clear and accurate monitoring. KPIs are quantifiable and assessable even during the ongoing process, with corresponding units assigned. The main benefit of implementing KPIs for a company is the ability to analyse individual processes through their overall performance, not just from a purely financial perspective. By introducing KPIs, each company gains an analytical tool quantifying process performance in relation to a set goal related to achieving the desired outcome. This can stabilize the quality and reliability of processes while simultaneously meeting normative requirements.

The research was aimed on evaluating the performance of production processes characterizing product quality. The target value for assessing the performance of the production process for part A, based on the number of non-conforming products, was defined as the value of INTppm. The target *INTppm* value, aligned with the company's quality objectives, was to achieve a maximum value of 2000 ppm for each evaluated order of part A. The achieved average value for individual part A orders during the monitored period, encompassing 16 initiated and completed orders, was 4443 ppm. As a result, the company's quality and process performance objectives for the specific part A orders were not met, and the process was evaluated as highly unstable. Based on the analysis of the causes of non-conformities in the analysed process, actions were proposed to address the identified quality problem. These actions are focused on a design modification of the lathe chuck and on timely diagnosis and maintenance of the problematic cutting insert, aiming to eliminate the identified quality issue.

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