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STROJNÍCKA FAKULTA
KATEDRA PRIEMYSELNÉHO INŽINIERSTVA

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WYDZIAŁ BUDOWY MASZYN I INFORMATYKI
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Content

Content

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USE OF NUDGING IN PERSONAL MARKETING

Abstract

The article deals with the task of improving conditions at the workplace as an integral part of personnel marketing. By creating favourable working conditions through nudging and using basic elements of industrial engineering, industrial enterprises influence employee behaviour. The aim of this article is to point out the possibilities of applying nudging in industrial enterprises to facilitate the correct decision-making and actions of employees.

Key words: Personnel marketing, Nudging, Employees, Work environment

1. INTRODUCTION AND LITERATURE REVIEW

By using the Nudge Theory, personalists can create a more supportive and productive work environment, encourage positive behaviours and help employees make better decisions that align with their well-being and career development. For any company, employees are the most important element, because it is employees who participate in generating profit and creating company value. The main goal of personnel marketing is the search and acquisition of quality workers and their subsequent retention in the company [1]. This requires taking care of employees and ensuring their satisfaction, and it is also important to understand all factors affecting the needs of the workforce within the company, such as the working environment, employee health, etc. [2]. Šlapák (2015) states that internal personnel marketing deals with processes associated with current employees [3]. It is essential not only for creating a productive and satisfied working environment, but also for minimizing the risk of departure of valuable employees. In industrial practice, it often happens that employees often do not know what to do, how to proceed in the performance of their work, or they don't know how to make decisions. Another case is situations where companies have established guidelines, standards, procedures, even employees have completed training or instruction, and for certain reasons the given instructions are not followed. This can be due to not learning them, forgetting them or simply by ignoring it. The above also refers

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to non-compliance with the rules of safety and protection of the health and life of employees. It is for such situations that we suggest using a method that was originally described in the field of psychology as a tool for subconsciously influencing people's behaviour and actions. This method is called nudging, and we can call it intervention or nudges in a person's decision-making process. Nudges are interventions, large and small, aimed at getting people to act in their own best interests [4]. So, a nudge is an intervention that preserves freedom of choice but guides people in a certain direction. A nudge is not a tax, a subsidy, a mandate, or a ban. The nudge is a warning: “If you swim at this beach, the current is high, and it can be dangerous.” They force us not to swim, but we can. When we get information about the number of calories in a cheeseburger, it's a nudge. If a utility sends a message two days before a bill is due, telling customers, "You should pay now or you'll be charged a late fee," that's a push. We can say no, but it's probably not in our best interest. Nudges help to cope with limited attention. A nudge can make us pay attention to phenomena in our surroundings [5]. A person who is "stale" is often unaware of this fact. True nudges appeal to a subconscious decision-making system that is governed by many cognitive tendencies. Another example is that people who say what others believe are more likely to be believed than those who say the opposite [6]. These compulsions can be extensive in nature, both aimed at making people act in their own best interests. In this article, we will present several examples of nudges from practice, in which decision-making and subsequent actions of employees of industrial enterprises are influenced.

2. METHODS AND METHODOLOGY

The main goal of the investigated issue is to point out the possibilities of using nudging in industrial enterprises. When formulating the main goal of the contribution, we were based on the fact that there are situations where all work procedures, instructions and health and safety measures are not followed at the maximal required level. These deficiencies occur in workplaces in various companies. In this contribution, we present nudging applications that we obtained from 4 industrial enterprises operating in Slovakia. The contribution consists of practical uses of nudging. Nudging applications were intended for production employees of selected industrial enterprises. The method of observation and, in one case, the measurement of noise values using a noise meter were used to collect information. The observation took place during the performance of work activities in real working conditions. The noise measurement took place during the separate operation of the individual machines to ensure the exact values of the individual devices. We carried out the observation before the application of nudge elements and after their application.

3. RESULTS AND DISCUSSION

3.1 Use of nudging in industrial enterprise 1

In industrial enterprise 1, we used a sound meter to measure the noise in the workplace. At the workplace, almost all machines are in continuous operation throughout the working hours. In this company, the analysis revealed a problem with noise, which reached values from 32 dB to 96 dB. The values of the given noise are not extremely high which is a problem because the employees think that these values are not harmful.

In fact, the given values can cause hearing damage with long-term exposure. In the following table, the specific values of the noise level are measured and recorded together with the health consequences. As part of the analysis, we found that nudge elements have a greater application at lower noise values. This is because employees do not immediately feel its negative effects on their health at lower noise levels. Table 1 shows individual noise levels and the health consequences they cause.

Tab. 1. Results of the action of measured noise (own processing according to [7])

Noise value at the workplace (dB)	**Health consequences**
32-69	Acceptable value of noise without health consequences
70-80	Absolute noise, which causes nervous irritation, disrupts the concentration of employees, and reduces the quality of work.
90-100	With long-term exposure, it causes deafness, fatigue and headaches.

Based on the listed findings, the industrial enterprise implements the use of nudging as a supplementary measure to the already valid legislative regulations. This additional measure consists of two parts. The first part was the creation of a slogan that reads "Let's save our hearing for more important things." The second part was the creation of posters with this slogan, the company logo and a description of the health consequences. (Fig. 1, left) shows an employee using personal protective equipment available at all workplaces in the company. These posters are intended to influence the actions of employees. It is important to place the poster (Fig. 1, right) as a nudging element in the place where the greatest influence and reach belongs to the employees who work in the given workplace.

Fig. 1. Nudging poster and its location in an industrial enterprise 1 [8]

3.2 Use of nudging in industrial enterprise 2

The identified problem in industrial enterprise 2 was the supply of the assembly line, which is carried out by means of a forklift truck. The logistics employee should continuously check the status of the input materials in the bins (which represents waste in the form of unnecessary routes) or the line operator will summon the logistics employee with a wave of the hand. Due to the performance of other logistics activities by logistics employees, the mentioned system is inefficient and the given method of supply causes downtime. The cause of waste in the form of logistic downtime is an inappropriate work procedure. For this reason, a signalling system was designed for better cooperation between the production operator and the logistics employee (Fig. 2).

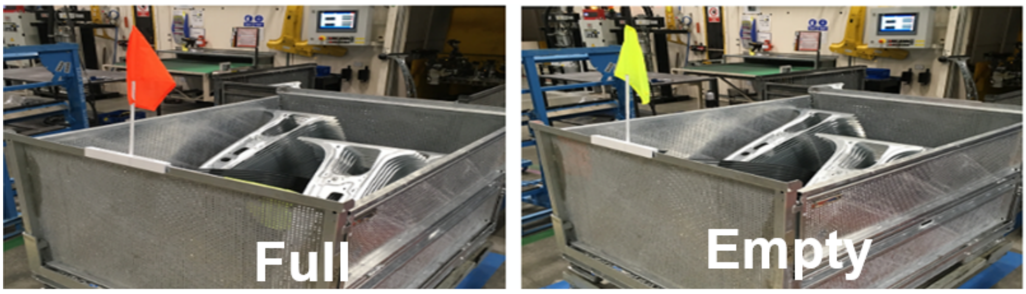

Fig. 2. Nudging during supply in an industrial enterprise 2 [9]

After applying nudging, the logistics employee does not have to come to the production facility to have visual contact with the material in the bins but can see a clear signal from a distance of 100m. In (Fig. 2), nudging is in the form of signalling for input materials, where green means everything is fine and there are enough inputs on the line. In the case of an orange flag, it is a missing material that needs to be delivered to the line.

3.3 Use of nudging in industrial enterprise 3

In industrial enterprise 3, nudging was applied for the needs of administrative activities when filling out forms, so that employees know which boxes and information need to be filled in the form. The form was pre-filled by default, and the employee's task was to record the measured time data in the fields marked in (Fig. 3).

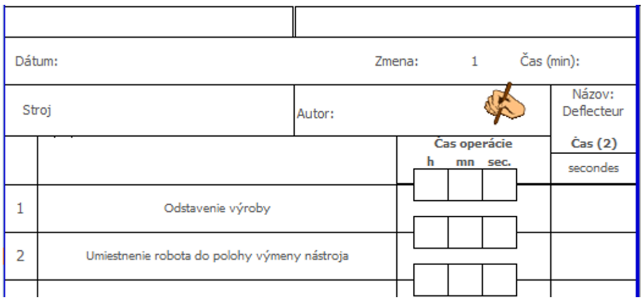
Dátum: Zmena: 1 Čas (min):
Stroj | Autor: | Názov: Deflecteur
Čas operácie h mn sec. | Čas (2) secondes
1 Odstavenie výroby
2 Umiestnenie robota do polohy výmeny nástroja

Fig. 3. Nudging in administrative activity [10].

3.4 Use of nudging in industrial enterprise 4

In industrial enterprise 4, there was a problem with the correct sorting of waste from rubber sealing profiles. The vulcanized material is classified in two ways. The first group of waste consists of vulcanized material without metal reinforcement. The second group of waste consists of non-conforming products created during joining - an imperfect joint of a seal or an incorrectly cut piece and other surface or deformation defects. The mentioned waste has metal reinforcement in it, which poses a problem during processing and recycling, and the given profiles often end up in the landfill. The application of nudging consisted in labelling individual containers according to the waste that belongs to the given container (Fig. 4).

Fig. 4. Nudging in waste sorting (own processing, 2024)

4. CONCLUSION

Improving working conditions, facilitating, and speeding up work activities based on desired behaviour and creating conditions for the purpose of satisfaction and subsequent retention of employees are very important. Also, compliance with any rules, whether for the efficient performance of work or compliance with health and safety regulations, is a necessary condition for the efficient functioning of the company. Therefore, every company should strive for continuous improvement and search for new methods to ensure this activity. Nudging is a method that can subconsciously influence the behaviour of employees and direct them to the necessary activity or to the use of protective equipment, even if they consider it unnecessary or burdensome. This method was not originally created directly for application in industrial enterprises and personnel marketing, but we believe that it has great application possibilities in this area. In the post, we presented four concrete examples of the practical use of nudging as part of the application of elements of industrial engineering. As visual elements are applied, the aim of which is to ensure the creation of favourable working conditions, facilitate the decision or influence the behaviour of employees in the desired direction, facilitate the very performance of work activities, which will contribute to employee satisfaction, faster adaptation of employees, adoption of a certain procedure, personal marketing measures are concretized. The stated facts will subsequently be reflected in the retention of existing employees, thereby achieving the fulfilment of one of the main tasks of personnel marketing, specifically internal personnel marketing.

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APPLICATION OF CHANGE MANAGEMENT IN THE IMPLEMENTATION OF GREEN PRODUCTION APPROACHES IN INDUSTRIAL ENTERPRISES

Abstract

Change management is the process of managing the transformation of organizations; it involves planning, implementing and monitoring change. There are several models of change management, with advantages and disadvantages. The article focuses on identifying the suitability of each model for specific situations in the organizational environment. The aim is to provide an overview of the advantages, disadvantages and potential benefits of these models so that managers can effectively manage change in their organizations.

Key words: Change Management, Green production, Change

1. INTRODUCTION

The necessity of implementing changes in the form of green production in industrial enterprises is based on the requirements for sustainable development and sustainability in all industrial sectors.

1.1 Sustainable development

Global challenges such as climate change, natural resource depletion and pollution require immediate and coordinated action given their relatively urgent nature. Proactive action on sustainable development issues may be the solution, which is essential to ensure a healthy environment and economic growth for current and future generations, as unsustainable economic models can have catastrophic consequences for the environment and human well-being [1]. Therefore, it is imperative that we examine

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and understand the linkages between economic growth, environmental factors and societal well-being in order to achieve sustainable development [2]. It is necessary to accurately identify and analyze potential problems associated with sustainable development, assess the potential of enterprises in a timely manner, and determine methods to enhance the sustainability of their development. In the market environment, sustainable enterprise development involves the search for new adaptive tools and methods to ensure it, which are not limited to determining the financial stability of business entities [3]. All this indicates the importance of the development and implementation of a management system for sustainable development of enterprises. The need for effective sustainability and the lack of theoretical and methodological regulations for the management of sustainable development of business enterprises confirm the relevance of the topic [4].

1.2 Green production

The promotion of sustainable development is ensured by a number of initiatives, in particular in the field of industry on the issue of green production. According to [5], green manufacturing is a type of modern production mode that mainly focuses on resource optimization and environmental protection. Reducing emissions and waste of any kind is the ultimate goal to be achieved in green manufacturing [6]. Legal entities usually lack the awareness to make the green transition on their own, and without government policy intervention, it is difficult for enterprises to make the green transition and implement green manufacturing [7,8,9]. Although green manufacturing can bring long-term benefits to the environment and society as a whole, employees and managers may face concerns about changing work practices, investment costs, and changing work environments [10]. Resistance to change in the context of implementing green manufacturing approaches can be even more complex given their environmental nature and potential impacts on existing manufacturing processes [11]. Resistance to change is a phenomenon that often occurs in the context of implementing new initiatives, including those that seek to promote sustainable development [1]. These resistances can arise for a variety of reasons, including fear of uncertainty, changes in one's own work, and a lack of awareness of the goals and benefits of proposed changes [12]. Recognizing these resistances and their causes is key to successful change implementation. Despite the challenges encountered, there are examples of successful implementations of green manufacturing principles that have been supported by thorough communication, consideration of employee perspectives, and investment in training and workforce development [2]. An important part of implementing green manufacturing principles is the involvement of experts from different fields, including environmental researchers, technical experts, and managers, to ensure a comprehensive understanding and successful implementation of new technologies and practices [13].

1.3 Change management

One of the main challenges of the progress of modern companies is their development and change in accordance with modern market principles of operation and the increasing demands of the external environment. The external conditions for the functioning of a modern organization concern various indicators of its activity, require flexibility of the management system, and therefore, an effective organizational structure as one of its most important elements [14]. Change is often necessary for a company to remain relevant and continue to provide viable solutions to a growing customer base. But although a company and its leaders may be aware of the need for change management, employees may resist because change can be difficult and uncomfortable [15]. Change management is the process of planning, implementing, and managing change in an organization to achieve positive results. It involves preparing for and engaging employees and other stakeholders in change to maximize fluidity and effectiveness [3]. Change management mainly focuses on maintaining financial and environmental continuous progress in market transformation. Business conditions are constantly changing and organizations should be able to respond and adapt accordingly through change management, which in turn will affect its sustainability and working methods [16].

2. METHODS AND METHODOLOGY

Implementing change in organizations, managing it effectively and successfully is key to achieving the stated goals of individual organizations in various innovation or other change projects. In the field of change management, models and tools have been developed to help organizations achieve various changes more successfully. Each model, tool offers specific approaches and strategies to address different aspects of change, from planning to implementation and tracking results. We proceed by describing selected change management models and their benefits:

2.1 Lewin's model of change

Lewin's 3-stage model is one of the best known and most widely used change management methods. This model was developed by psychologist Kurt Lewin and consists of three main phases [17]:

- The unfreezing phase - this phase focuses on preparing the organization for change by identifying existing patterns of behavior that need to be changed.
- Change Phase - the unfreezing phase is followed by the change phase, during which new processes, strategies and structures are implemented.
- Freeze Phase - the final phase deals with establishing the new practices and ensuring that the changes become part of the organization's normal practice.

2.2 KAIZEN

Represents a Japanese concept focusing on continuous improvement within an organization to achieve gradual and lasting changes in performance, quality and effectiveness. This approach to change management is often associated with the lean management philosophy and is known for its emphasis on employee participation and systematic improvement [18] (Imai, 1986).

2.3 Dunphy and Stacy model

Dunphy and Stacy's model of change is a theoretical framework that focuses on the identification and management of change in organizations depending on the context of the external environment. The model distinguishes four types of change: adaptation, transformation, renovation, and reconstruction, with each type appropriate for different levels of dynamics in and around the organization [19] (Dunphy & Stace, 1993).

2.4 Kotter's model

The Kotter model of change, developed by John P. Kotter, is one of the most widely used models of change in organizations. The model consists of eight steps to help organizations achieve successful change implementation. The steps of applying Kotter's model are creating an urgent need for change, creating leadership for change, creating a vision for change, communicating the vision, removing barriers, achieving short-term wins, solidifying the change, and ensuring long-term sustainability [20].

2.5 Mintzberg and Quine's model

Mintzberg and Quine's model of change focuses on understanding change as a complex process that is influenced by the interaction of various factors and organizational dynamics. This model emphasizes the importance of understanding the culture and structure of the organization in managing change [21].

2.6 The learning organization

The learning organization is a concept that focuses on the ability of an organization to adapt and grow through continuous learning and adaptation. This approach to change management is based on the premise that organizations that are able to learn and adapt effectively are more competitive and able to achieve sustainable success in today's dynamic environment [22].

2.7 Prosci ADKAR model

The Prosci ADKAR model is a change management framework that focuses on the individual aspects of change and transformation in organizations. The model is based on five key dimensions that guide individuals through the change process. The specific dimensions are Awareness of the need for change; Desire to support and participate in change; Knowledge of how to make change happen; Ability to apply new skills and behaviors; Reinforcement to make change stick [23].

2.8 The McKinsey 7-S Model

The McKinsey 7-S Model is a management framework developed by McKinsey & Company that focuses on a comprehensive assessment of an organization and the identification of key factors that influence its success and effectiveness. The model consists of seven interrelated dimensions that shape and influence the organization and they are Strategy, Structure, Systems, Shared Values, Style, Staff, and Skills [24].

3. RESULTS

Each of analyzed models has its own strengths and weaknesses and is suitable for different types of change and organization. Choosing the right model depends on the specific needs of the organization, the type of change, the organizational culture and the objectives to be achieved. We then describe the important areas between the different methods, their strengths and weaknesses, and their potential benefits based on a study of the professional and scientific literature.

Advantages and benefits of each method:

- Lewin's change model: it is simple and easy to understand, suitable for smaller changes or organizations starting out in change management.
- Kotter's 8-step model: provides a comprehensive approach and emphasizes the importance of communication and employee involvement.
- ADKAR model: focuses on the individual and their response to change, which helps address resistance to change.
- McKinsey 7-S model: provides a holistic view of the organization and shows how the different elements are interconnected and how changes in one area can affect others.
- KAIZEN fosters a culture of continuous improvement and engages all employees in the improvement process, increasing productivity and quality.
- Dunphy and Stacy's model provides a framework for selecting an appropriate change strategy based on the context and need of the organization.
- Mintzberg and Quine's model highlights different aspects of strategic management and shows how different approaches to strategy can influence change in an organization.
- A learning organization promotes flexibility, innovation and the ability to adapt quickly to changing conditions, thereby enhancing long-term competitiveness.

4. CONCLUSION

Overall, the analysis shows that models such as the Learning Organization and KAIZEN seem to be suitable against the evaluation criteria of employee involvement, flexibility, time and money intensity of each model, which means that they can help to better implement green manufacturing approaches. However, it is important to consider each model in relation to the specific needs and objectives of the organization. Using a model in change management provides businesses with a structured and systematic approach that reduces chaos and uncertainty during change. Models help to clearly define the steps to be taken, engage employees, and communicate change effectively. This leads to better coordination, faster adaptation, reduced resistance to change, and improved overall organizational performance. In addition, the models allow progress to be monitored and evaluated, ensuring that changes are sustainable and deliver the expected results. In conclusion, evaluation is relative, and each problem or change is individual and requires a specific approach and method. The limit of the presented analysis is that the results are based on subjective evaluation based on theoretical assumptions.

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INNOVATION OF PRODUCTION PROCESSES VERIFIED WITH THE HELP OF A SIMULATION MODULE

Abstract

Manufacturing processes often require innovation. These innovations often mean changes that no one expected at the beginning. All matters related to production processes can be projected into digital form. Subsequently, all changes can be made and verified first on the digital platform, and after obtaining the necessary information, changes can be made in real production, or part of it. Such solutions are often worth implementing even for minor planned changes. In the case of major interventions in production, or when planning new production processes, it is nowadays quite desirable and necessary.

Key words: Simulation, Production processes, Innovation

1. INTRODUCTION

In today's competitive industry, continuous improvement of production processes is a necessity for the success and efficiency of a company in which digital technologies and intelligent solutions are constantly pushed. This phenomenon, known as Industry 4.0, is redefining the way companies carry out their production processes and manage their operations. We are thus moving towards the creation of "smart factories" where advanced technologies such as robotics, the Internet of Things (IoT), artificial intelligence, and augmented reality are used in order to achieve a higher level of automation, flexibility, and efficiency. My goal is to identify and implement innovative solutions that will increase the efficiency of the production process of interchangeable superstructures and bring significant improvements in the performance and quality of products. As part of my work, I focused on the transformation of the traditional process of manual blasting of products to blasting using a modern blasting machine. This step not only increases the speed and accuracy of the process, but also significantly reduces the costs and risks associated with manual work, effectively responding to the requirements of Industry 4.0.

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Fig. 1. Exchangeable superstructure

2. PRODUCTION PROCESS OF THE EXCHANGE SUPERSTRUCTURE

In the next part of the post, we will briefly describe the production process of the production of the exchangeable superstructure (Fig. 2). The company in question is engaged in the production of exchangeable superstructures for the chassis of cargo trailers of trucks and freight trains.

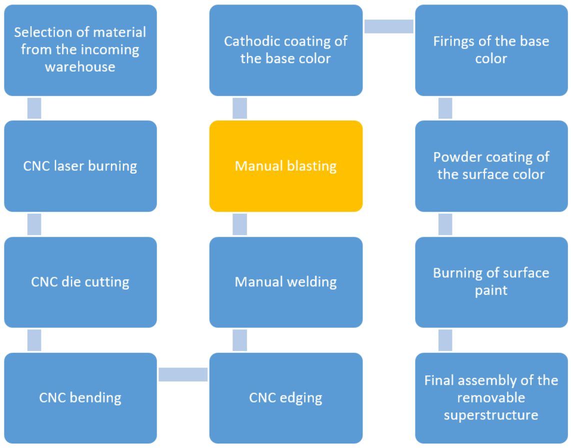


Fig. 2. Schematic representation of the production process of the exchange superstructure

At the beginning of the production process during the production of the replacement superstructure, sheet metal and steel profiles from the material warehouse enter the production, which are laser-cut according to the specified dimensions into sheets of sheet metal, cut out and bent. Laser burning is carried out on the latest CNC machines. The process of laser division of the material is followed by the punching operation. After the punching operation, the specific parts go to the bending process on a CNC bending machine. In the next step, the components are transferred to CNC bending. CNC bending enables the creation of parts with simple bends, which can be up to 4000 mm long and up to 10 mm thick. Manual welding follows, subgroups are welded using a compact welding machine, and then the welded subgroups (side walls, floor, roof) of the replacement superstructure are welded together and thus the already completed product of the replacement superstructure is welded. The next operation that follows is manual blasting of the replacement superstructure (Fig. 3). A manual pneumatic blasting device is used. Blasting time is 3-4 hours. Before the operation of cathodic immersion painting, it is necessary to blast the welded exchange superstructure for the sake of high-quality painting and thorough corrosion protection.

Fig. 3. Manual blasting of the exchange superstructure

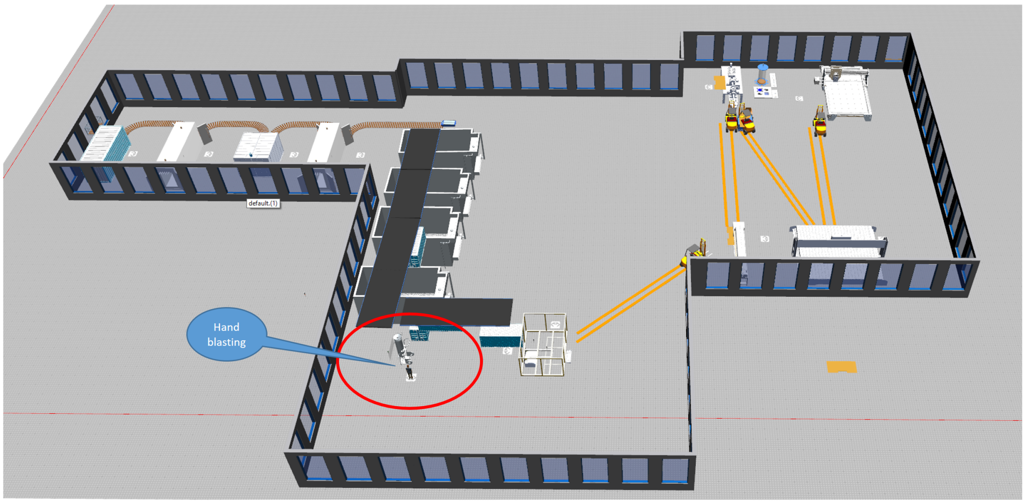
The process of cathodic dip painting follows, this guarantees long-term anti-corrosion protection for all products, high resistance to mechanical damage, resistance to salt water and chemical substances. After rinsing in demineralized water, the dyed replacement superstructure is moved to the firing oven, where it is fired at 180 °C for 50 minutes. Next, the replacement superstructure is moved to the powder booth where the surface powder paint is applied to it, the shade of the powder paint is determined according to the customer's request. The product powdered in this way goes into the firing furnace, where the powder at a temperature of approx. 160-200 °C polymerizes and spreads over the entire surface, creating a perfectly smooth surface. After firing, the front roll-up door, interior wooden floor and interior and exterior fittings are installed on the replacement superstructure. The last operation to be performed on the replacement superstructure is gluing the advertising description with the prepared foils.

3. DESCRIPTION OF THE INNOVATION IN THE PRODUCTION PROCESS AND ITS SIMULATION VERIFICATION

The innovation in the production process consists in the replacement of manual blasting with an automatic self-acting blasting machine.

3.1 Description of the current state

Two employees participate in the manual blasting of the replacement superstructure, who load the superstructure onto the transported trolley with the help of an overhead crane and manually push the superstructure into the blasting cabin. Using manual pneumatic blasters in spacesuits, they blast the entire replaceable superstructure. Blasting time 3-4 hours when blasting by two workers. Disadvantages of manual blasting: strenuous work, environment harmful to health, imperfectly blasted surface, difficult handling of the product. We projected the original state of production into digital form (Fig. 4). It is clear from the simulation model that in 30 days of the simulation, the production unit completed 33 products. This number of products corresponds to the actual state that the production is able to produce in such a time.



Simulation time:30:00:00:00.0000

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
Výstup_z_výroby	vlačik	5:00:59:13.5334	33	0	76.65%	23.35%	0.00%	8.38%	

Fig. 4. Simulation model of production in its original state

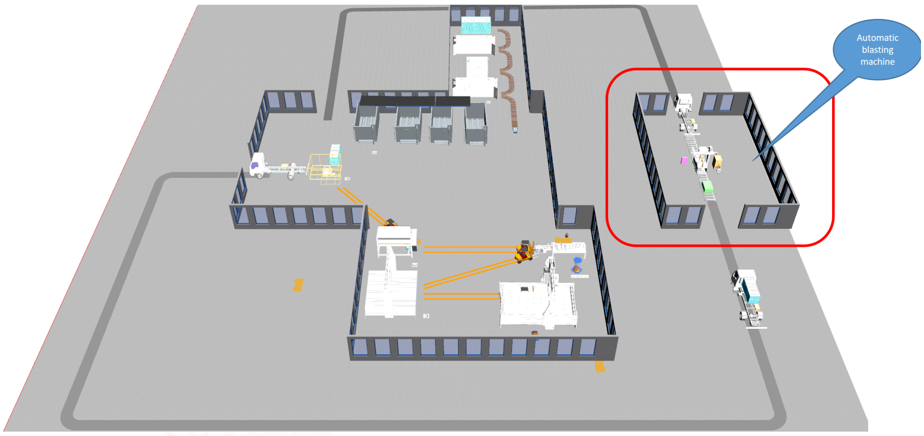
3.2 Production innovation proposal

The production innovation will consist of the replacement of the manual blasting workplace with an automatic blasting machine that does not require operator operation (Fig. 5).
This machine is continuous and works all the time. The parts to be blasted move smoothly through the machine on rail carriages using a rope system that drives them. Rail trolleys are manufactured in-house, they are adjusted to the manufacturer's recommended height. Loading and unloading of parts onto railcars is carried out using equipment that the company already has at its disposal, so there is no need to deal with its purchase. The part smoothly enters the input chamber of the machine through the sealing rubber hinges and then continuously passes through the blasting tunnel, where it is automatically blasted using the throwing wheels. It continues smoothly into the exit chamber and leaves the machine again through the sealing rubber curtains to

the unloading place. Fans are placed at the outlet of the outlet chamber to remove the remains of the blasting medium from the surface of the part. If there is a need to manually blow off complicated parts that the fans cannot reach, the operator can use a manual blasting chamber. A slatted floor conveyor system is installed at the place of unloading of blasted parts. In case of spillage of blasting medium during unloading, this medium is returned to the machine system by means of a floor conveyor. The entire blasting process takes place automatically using the Siemens SIMATIC control program. After the part is unloaded from the railcar, the operator reverses the rope system and the railcar returns to the front of the machine to load the next part for blasting, starting a new work cycle.

Fig. 5. Automatic blasting machine

The simulation model of the innovation in the production process shows how the production should look after the implementation of the automatic blasting machine (Fig. 6). Considering the size of the products it is supposed to process, this equipment is also quite large in size and cannot be integrated into the current hall. It is therefore necessary to build a separate new hall where this machine will be installed. As can be seen on the simulation model, in addition to the cancellation of the original workplace where manual blasting was carried out, it is also necessary to ensure the transportation of products for automatic blasting and also from it back to the production hall, considering that it was not possible to build this new hall closer to the current one.



Simulation time:30:00:00:00.0000

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
Výstup_z_výroby	vlačik	4:01:13:46.3470	44	0	75.43%	24.57%	0.00%	10.42%	

Fig. 6. Simulation model of the proposed state of production

As can be seen from the simulation model of the proposed state, taking into account all the peculiarities that need to be taken into account, the final output of the production process increased from 33 pieces to 44 pieces. The new way of blasting parts speeds up production despite the need for inter-site transport, is less laborious and the quality of the products has also increased.

4. CONCLUSION

Based on the digitization of the production process, it was possible to test and design how the entire production process might look after the implementation of the innovation in the core of the production process. When solving how to integrate the innovation into the existing production hall, the problem with the large dimensions of the new equipment, which had to be placed in the new hall, was also solved. Considering the size of the land and other buildings around the current production hall, it was necessary to place the new hall at a greater distance from the current one. This also required the proposal of inter-object transport. The products need to be moved from the current hall to a new hall with automatic blasting and, after its implementation, back to other operations that take place in the soil production hall. After implementing all the changes, the simulation model shows an increase in the number of products for the same simulation run time as in the original production process.

Acknowledgment

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PROPOSAL OF LIVER ON A CHIP DEVICE

Abstract

Organ-on-a-chip technology, also referred to as tissue chips, contains engineered or natural miniature tissues derived from various bodies which grow in miniaturized fluid channels shaped into glass or polymer, and others biocompatible materials. This technology was developed during a few the last ones decade interaction a few scientific disciplines including biology and engineering. The main one the aim was to make a brief theoretical overview organs on a chip and the subsequent design of liver on a chip according to theoretical foundations and studies.

Key words: Microfluidics, 3D printing, Organ on a chip, Tissue engineering

1. INTRODUCTION

Organ-on-a-chip (OoC) technology represents a groundbreaking approach in biomedical research, enabling the simulation of physiological environments of organs in vitro. By closely mimicking organ function and response, OoC models facilitate the study of various diseases, drug reactions, and toxicological processes in controlled settings. The primary goal of OoC technology is to recreate three essential aspects of human physiology: multicellular vascular or epithelial interfaces, parenchymal cell organization at the tissue level, and methodical interaction with microbial communities. Central to the development of OoC devices is the careful selection of materials. Materials play a pivotal role in microfluidics and OoC technologies, influencing biocompatibility, optical transparency, gas permeability, and fabrication costs.
In this article, we present a liver-on-a-chip device designed for drug testing and toxicity assessment. Liver toxicity is a significant factor in drug development failures, making the accurate replication of liver function crucial. Our liver-on-a-chip model utilizes a microfluidic channel lined with hydrogel for optimal cell adhesion. We emphasize the importance of selecting the appropriate cell source, particularly hepatocytes, for accurate modeling of liver function.

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2. MATERIALS AND METHODS

OoC enables researchers simulate the physiological environment of an organ and study its function and response to various stimuli. These models can be used for studying various diseases, reactions to drugs and toxicology research in controlled environment without the need of animal testing or tests on patients. [1,2] The main one goal of OoC technology is to restore three key aspects of human physiology:

- multicellular vascular or epithelial interfaces bodies which serve as barriers in tissues (blood vessel networks, the lung, and the gut),
- organization parenchymal cells at the tissue level which oversees key functional properties of the organ (the liver, heart, skeletal muscle, and tumours) and
- methodical interaction microbial communities (drug absorption, distribution, metabolism, and elimination involving the gut, circulation, liver, and kidney). [1,2]

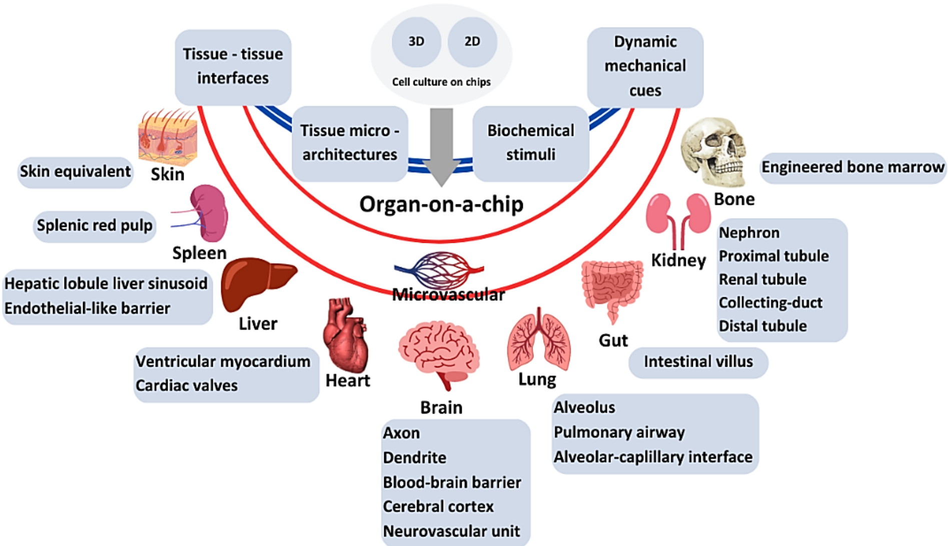

Fig. 1. The organ on chips concept of modeling and their existing simulation of functional units

The organ-on-a-chip (OoC) devices accurately represent human physiology in vitro, so selecting the appropriate materials is critical. In general, material considerations include non-toxic to cells, gas permeable, optically transparent for microscopic imaging, costs of the materials and the fabrication process, and the ability to model specific properties of organs. Although polydimethylsiloxane (PDMS) is still the most common material for laboratory research, emerging materials such as hydrogel, paper and hybrid materials are being developed and used. [3-8]

In particular, the choice of cell sources is crucial for organ-on-a-chip models. Animals provide the majority of the cell types utilized in contemporary experimental models. Yet, tissues derived from animals cannot perfectly replicate the complexity of the human experience due to notable physiological differences. Furthermore, they frequently serve as the main cause of failure in the drug-development process, particularly in its later stages, and they do a poor job of representing human illnesses. Many human immunological and neurological problems, such as autoimmune diseases, cerebral tumors, and conditions involving the immune system and the brain, lack animal model systems. Therefore, human cell sources are necessary for the creation of ideal in vitro model systems because of their inherent genetic mutations and variations.

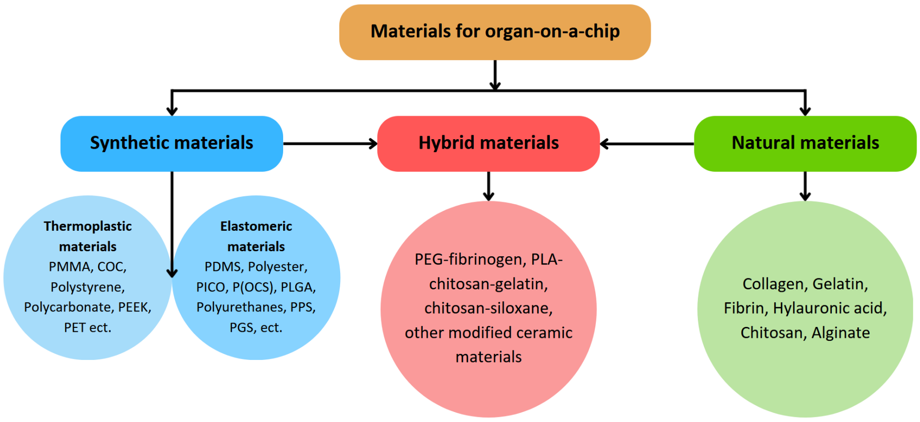

Fig. 2. Materials used in organ-on-a-chip devices [3-15]

OoC devices are designed to mimic the structure and function of human organs in a laboratory setting. There are currently several types of OoC devices that have been developed, each focusing on a specific organ or tissue. Some of the most well-known OoC devices include gut-on-a-chip, heart-on-a-chip, skin-on-a-chip, kidney-on-a-chip, lung-on-a-chip or liver-on-a-chip. There are also ongoing efforts to develop OoC devices for other organs and tissues, for example lymph nodes.

2.1 Organ-on-a-chip design

The chip can be produced in a variety of structural shapes, depending on the desired use and the cell culture technique: membrane structures, microchannels, culture chambers and multi-structured organ chips. Although there is a wide range of OoC systems and devices, many of them share similar features. The chip's body contains the channels or chambers as well as any extra integrated parts like sensors, electrodes, or valves. Because the chips are gas permeable and optically transparent, they usually facilitate easy imaging, observation, and the diffusion of gases such as carbon dioxide (CO2) and oxygen (O2). The microchannels on the chip are made to resemble the architecture of the organ under study. Human cells and tissues line the channels, and a network of pumps and valves replicates the organ's physiological conditions, including blood flow, oxygenation, and nutrition.
For the study of organs, there are many chip designs with variations in size, diameter, number of channels, channel shape, and other geometrical properties. Hence, the design is organ-oriented, and the corresponding features are specified accordingly. OoCs can typically be divided into three categories based on the number of their compartments/channels and how these channels are organized: single-channel chips, double-channel chips, which include sandwich designs and parallel designs, and multichannel chips.

3. LIVER ON A CHIP DEVICE

For liver-on-a-chip design we chose to focus on using chip for drug testing and liver toxicity. Liver toxicity is one of the major reasons why drugs fail. This liver-on-a-chip is designed with one microfluidic channel. The channel should be lined with hydrogel for better cells adhesion. Cells would be distributed inside the medium and they would adhere to the walls of the channel. The chip was designed in SolidWorks and the final models of variants were edited in Autodesk Fusion 360.

Fig. 4. Liver-on-a-chip design with one fluidic channel

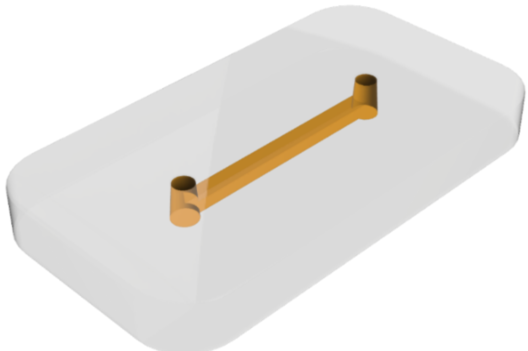

Fig. 5. Liver-on-a-chip for drug toxicity testing

The performance and functionality of the liver organ-on-a-chip microfluidics device are related to the cell type used in the system. The liver cells can be obtained from various resources. This can affect their functionality and the pharmacokinetics and toxicity testing results from the microfluidics organ-on-a-chip. Thus, a major concern for in vitro modeling of the liver is the cell source. 60% of the liver is composed of the hepatocytes as the parenchymal cells while multiple other non-parenchymal cells constituting the other 40%. We would suggest using hepatocytes. Hepatocytes can be derived from human primary cells, animal-based cells, induced pluripotent stem cells (iPSCs), or immortalized cell lines. Some of the commonly used hepatocyte cell lines include HepG2, HepaRG, Huh7, Hep3B, and SK-HEP-1. [4]
This liver-on-a-chip could provide a dynamic environment for cell culture, as was already mentioned. Real-time metabolic analysis is necessary in this dynamic context rather than the more traditional end-point evaluation. Electrodes and monitoring systems can be used in cell culture when microfluidic chips are made to be modular. As a result, the analysis is not restricted to end-point analysis and the impact of different factors on metabolism may be observed in real-time. In this context, electrochemical sensors are typical. Adherent cells have been the target of the majority of the sensors used to detect metabolism. Non-adherent cell systems are quite uncommon. These electrochemical

sensors can be used for measuring the following parameters: oxygen (indicative of respiration), glucose and lactate consumption (representative of energy metabolism), pH (acidification indicator), and reactive species (such as ROS or RNS). [4,14]
The metabolism rate can be monitored by placing measurement electrodes underneath the culture chambers or the collection microfluidic channels and reading out the metabolite concentrations. The functionality and intended use of the electrodes determine where they should be placed. For instance, it is advised to place some enzyme-based electrodes next to the outlets rather than the culture microchamber since they can produce hydrogen peroxide. [14]

4. RESULTS AND DISCUSSION

Organ-on-a-chip (OoC) technology offers a promising alternative to traditional methods for studying human physiology and disease. Key considerations in OoC development include the selection of materials, chip design, and cell sources. Materials must be biocompatible, gas permeable, and optically transparent to simulate organ properties effectively. Chip designs vary based on organ type, accommodating different cell types and physiological conditions.
Human cell sources are preferred for OoC models due to their genetic relevance and ability to replicate human physiology more accurately. Hepatocytes, for example, are crucial for liver-on-a-chip models, enabling studies on drug metabolism and toxicity. Real-time metabolic analysis enhances the utility of OoC devices, allowing for dynamic monitoring of cellular responses to stimuli. Electrochemical sensors facilitate the measurement of key metabolic parameters, providing valuable insights into drug effects and cellular processes. Continued research and innovation in OoC technology hold promise for advancing drug discovery, personalized medicine, and our understanding of complex physiological interactions.
Due to the scope limit of this work, this paper contains one design for liver-on-a-chip device. Renderings of designs that were made in Autodesk Fusion 360 were visually adapted to the described materials that should be used for construction. In the future, the studied issue is open to the solution of other problems. The first big step would be fabrication and testing of all the variants.

5. CONCLUSION

Organ-on-a-chip technology offers a promising approach to studying human physiology and disease in vitro, reducing the reliance on animal models and patient trials. By accurately replicating organ function and response, OoC devices provide valuable insights into drug development, toxicology, and disease mechanisms. The selection of appropriate materials, cell sources, and chip designs is crucial for the success of OoC models, ensuring biocompatibility, physiological relevance, and experimental robustness. Advances in real-time metabolic analysis further enhance the functionality of OoC devices, enabling dynamic monitoring of cellular processes and metabolic pathways. Continued research and innovation in OoC technology hold great potential for advancing drug discovery, personalized medicine, and understanding complex physiological interactions in health and disease.

Acknowledgment

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CREATING LABORATORY EQUIPMENT USING 3D PRINTING

Abstract

This paper aims to use 3D printing to create a functional model of a conveyor belt as part of laboratory equipment. The first part of the article explains the theoretical background of 3D printing in general, specifically the FDM method as the most widely used 3D printing method. All this knowledge was later used in the practical part. In the practical part, the process and procedure of creating our conveyor belt is elaborated. From the creation of the model in the program to the actual printing by our designated printer. The last part of the article is the result in the form of a functional conveyor belt and also a discussion and shortcomings found by the authors during printing, assembly, and use.

Keywords: KISSlicer, 3D print, Filament, Conveyor belt

1. INTRODUCTION

Today's era in the field of 3D printing is advancing with great potential in various fields including industry, healthcare, and architecture. This technology enables the creation of three-dimensional objects from digital models, thus simplifying and innovating manufacturing processes. Its impact on manufacturing processes and creative solutions opens new possibilities and improves existing processes. This paper aims to review and analyze the different aspects of 3D printing, its functioning, technological procedures, and current trends, and finally, the use of 3D printing as a functional tool for equipping the department's laboratories. We aim to provide a comprehensive overview of this technology and its impact on the current industrial and societal context [1].
FDM printers work on the principle of sequential deposition of plastic material to create 3D objects. This technology has become an important part of various industries including industry, education, and research. FDM printers allow you to work with various plastic materials, which opens the door for creating prototypes, personalized products, and spare parts. It is important to note that these printers are affordable and suitable for

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home use but have their limitations, which include lower printing accuracy compared to other types of printers.

Fused Deposition Modeling is currently the most commonly used 3D printing method (Fig. 1). It is based on the principle of depositing layers of molten plastic string (filament) through a print head (extruder) which contains a heated nozzle at the end [2]. Feeding and precise dosing of the filament is provided by a stepper motor. The molten material is deposited layer by layer on the heated pad (heatbed). The pad is heated to prevent the 3D object from twisting due to the temperature difference at the bottom and top of the printed object. The nozzle is heated to the melting temperature of the plastic and can be positioned using stepper motors in three axes - X, Y, Z. Often the print head is only positioned in two axes, e.g. X, Y, and the print pad is positioned.

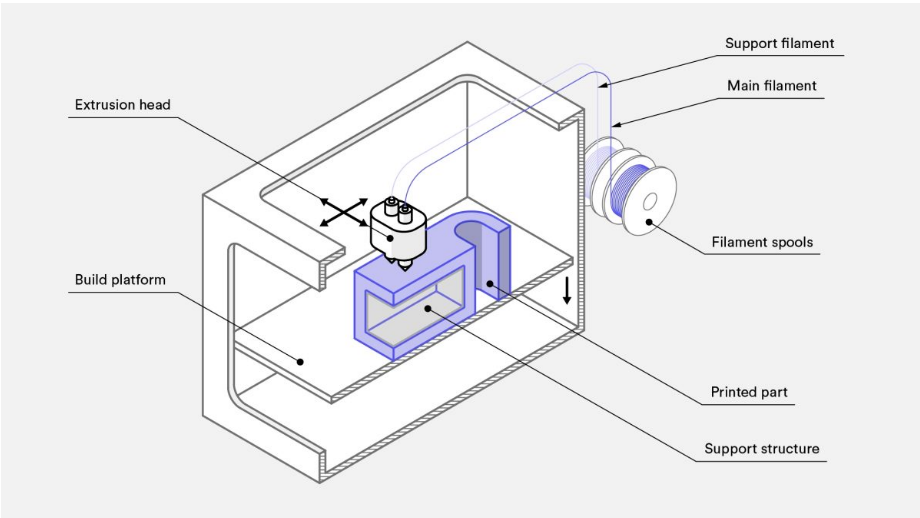

Fig. 1. The process of 3D printing by FDM [4]

This method is used for Rapid Prototyping purposes. If a company produces metal or plastic parts using the casting method, it can first print a prototype of the designed part in a 3D printer, check the design for accuracy, and if the prototype meets the expectations the production of the molds for casting the parts starts and mass production starts. The disadvantages of this technology are the long printing time, the wide variance in print quality, which depends on the printer model and the material used, or the need to use support layers, especially in parts of overhangs [5].

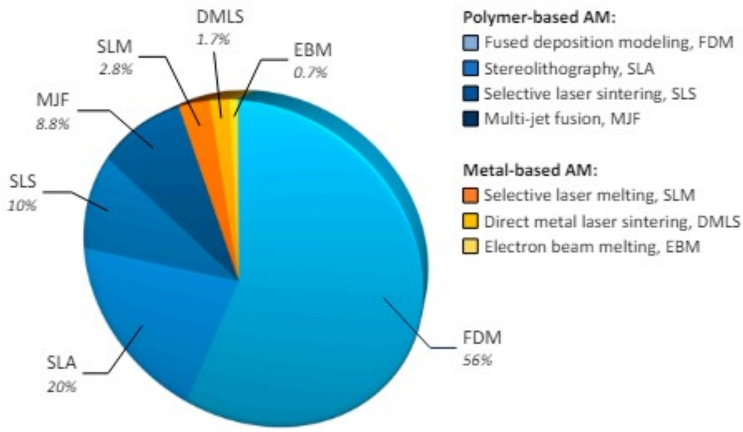

Fig. 2. According to a survey conducted in 2023, FDM is being used by 56% of the businesses active in 3D printing [3]

The advantage is that they are affordable, can be afforded by a company, or can be used at home for home use. For this method, it is most suitable to use plastic material. For this reason, manufactured objects have limited areas of application, e.g. they are not suitable for applications in environments with high temperatures and cannot be subjected to high mechanical loads.

2. THE PROCESS OF CREATING A 3D MODEL OF A CONVEYOR BELT

The model procedure was designed in SolidWorks, where we visually modeled the individual parts of the conveyor belt. After modeling, the assembly mode was used to assemble our parts into the final model. The saved component model in STL format is then loaded into the KISSlicer home environment. [6] From there, we work with the settings needed to print our model. We set the orientation and parameters of the model such as support structures, material density, print speed, and layer thickness. Based on these settings, the program divides the model into layers that define the trajectory of the print head. We do not interfere in any way during the printing process but leave the printer running until the entire model is printed or when the filament needed for finishing is changed. The finished 3D model needs to be machined by removing the additional material and making visual adjustments [7].
The final assembly in SolidWorks is shown in (Fig. 3). All parts are colored and differentiated so that the individual parts can be visually distinguished. The total length of the final conveyor model of the conveyor belt is 365mm.

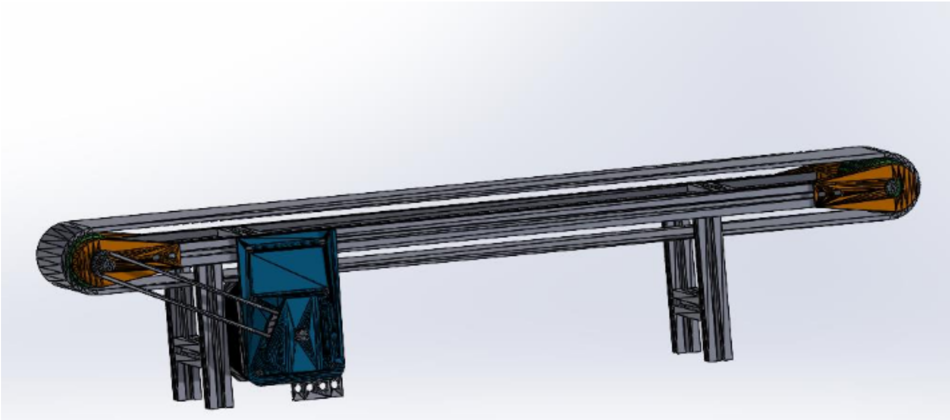

Fig. 3. Model of a conveyor belt as an assembly in SolidWorks

2.1 The process of printing individual components

The models that have been designed and modeled in SolidWorks are gradually transferred to the correct stl format. The stl. was then loaded into KISSslicer and printed. Different fill was used for all components to ensure strength. Printing was without complications as the printers were in perfect condition, calibrated and the highest quality materials were used. The following table shows the components and the amount of string and length of string that were used for 3D printing [8].
Most of the components were printed from PLA material except for the belt itself, which was printed from flexible TPU string. The total print consumed 68.95m of filament and took 36 hours to print and 52 min.

Tab. 1. Processed print details in KISSlicer

NAME	QUANTITY	INFILL %	SUPPORT	MATERIAL	FILAMENT	PRINT TIME
Bearing holder	4	25	N	PLA	5.28m	2:17:20
Roller	2	25	N	PLA	8.94m	3:05:32
Hor. pillar	2	100	Y	PLA	11.60m	10:42:20
Ver. pillar	6	100	Y	PLA	7.07m	06:31:37
L-profile	8	100	N	PLA	5.51m	01:54:54
T-profile	4	100	N	PLA	2.75m	58:26:00
Belt	1	50	N	TPU	27.80m	11:21:40
				Σ	**68.95m**	**36.52**

3. RESULTS AND DISCUSSION

All the necessary components for assembling the 3D model of the conveyor belt were precisely prepared and placed on the workbench, together with adequate tools for assembly. The first step was to adjust the longest parts of the structure by 3cm, due to the shrinkage of the belt, and then insert the bearings into the prepared sections. These sections were bonded together using a suitable adhesive, which ensured the strength

and reliability of the connection. This was followed by assembling the legs so that the conveyor belt stood stably and evenly on the surface. Here too, we applied adhesive for a perfect connection of the parts of the structure. We added supports to the first constructed part to ensure its stability and again used glue to connect them. The next step was to fit the strip rollers, which required minor modifications for the insertion of the 5mm diameter, 110mm long rods.
We then inserted these rollers into the bearings so that the structure would hold the belt firmly. After stretching the belt, we finished the top of the conveyor. Finally, we attached the pre-prepared legs, using the included L-shaped reinforcements to improve stability. We fastened all components firmly and securely using M3 screws. The construction of this model was not characterized using complicated procedures, but rather by simple joining methods such as gluing and the use of screws. In the attached picture (Fig. 4) the finished model can be seen. Finally, we performed the linking and lowering of the belt, with the motor located at the rear of the structure. We carried out this integration and launching process in the Department of Industrial and Digital Engineering.

Fig. 4. Finished conveyor belt construction

However, several problems were encountered after the conveyor belt was launched:

- **TPU material**: the material from which the conveyor belt was formed is characterized by elasticity. However, this is always dependent on the thickness of the wall of the extrusion. In our case, it was 2 mm, which was sufficient to stretch the conveyor belt in only a negligible amount of time. The manufacturer claims stretching of the TPU printout by up to 400%, which in this case we are far from confirming. Another crucial factor was the 3D printing work area, which is 250mm, which was also insufficient for the required size. The solution could be a design like tank tracks, where the parts would be joined together to form a functional unit virtually indefinitely.
- **Structure**: a structure has been designed for this solution that is already strong in terms of strength required 100% filling of the prints. This wasted a considerable amount of string. A thicker structure with a stronger wall (at least 5mm) could be a solution. As such the wall could also withstand the stresses and the infill could be reduced.
- **Print run**: for the PLA prints, the print run was excellent. There were not any failures. In the case of printing from TPU material, it was different. TPU as a flexible string was stuck in the feeder and was very easy to grind. So,

the printing process had to be checked more often than with other materials or restarted. Even after adjusting the feeder to the optimum level, the process did not improve.

4. CONCLUSION

In the practical part of this article, we have dealt with the creation of the conveyor belt model using the relevant programs and 3D printing. The aim was to create a device that would be functional for laboratory use and would become part of a PLC system. We went through all the stages of development, from creating the models in SolidWorks to setting the parameters for printing in KISSlicer, to the 3D printing itself. This process allowed us to experiment with different materials, print settings, and optimization processes [9]. The result was the successful realization of a functional model of the conveyor using TPU material, which clearly showed us the benefit of 3D printing for practical applications, for example using this model as a prototype for testing before actual mass production or using it as a tool for educational purposes or scientific research. Overall, we concluded that 3D printing has incredible potential to transform industry and society. Its importance is not only in creating prototypes but also in creating innovative solutions and improving existing processes. It is fascinating how 3D printing can make the production of prototypes and special products faster and cheaper. It's fascinating the way 3D printing can speed up and cheapen the production of prototypes and specialty products. I see it as a key element for the innovation and development of many industries, including the industry, healthcare, architecture, and even art [10].

Acknowledgment

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SOFTWARE DEVELOPMENT FOR CONTROLLING ROBOTIC DEVICES USING VIRTUAL DATA GLOVES

Abstract

In the current era of technological progress, the use of robotic devices is becoming increasingly widespread across various industrial sectors. To control these devices in an efficient and intuitive manner, the development of interactive user interfaces represents a key area of research. This article focuses on the development and implementation of a software solution for controlling robotic systems using virtual data gloves. This research opens up new possibilities for the development of interactive and immersive technologies in robotics and provides a foundation for further innovations in the fields of virtual reality and automation.

Key words: Software, Data gloves, Virtual reality

1. INTRODUCTION

In the future of industrial manufacturing and services, a significant increase in the importance of comprehensive integration is anticipated. Strategic approaches focus on integrating new progressive and intelligent control systems with technologies based on the internet and networks. This integration will enable efficient exchange of information and communication between people, manufactured products, production means, as well as entire production systems and their networks. The growing need to integrate and connect various new technologies stems from the requirements for more efficient operation of technical devices and systems, whether in robotics or other industrial sectors. Developments in information, communication, and computer technologies significantly contribute to the advancement of virtual reality, which is particularly applicable in robotic systems. Technical and software support for systems utilizing digital and virtual technologies represents a key innovation trend, especially in the design and development of robotic systems. Virtual reality offers users the ability to interact with a simulated environment in real-time through multiple sensory channels. [1] Simulations can be conducted using devices such as data gloves or virtual helmets. Interaction in a robotic system takes place in a virtual environment, where the programmer can simulate robot movements and observe them from various angles using devices like a data glove, tracking device, and virtual helmet. [5] These tools allow for detailed display of aspects

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that might not be visible in the physical environment, such as movement trajectories, dynamic behaviors, path determination, accelerations, and component interpolations. After completing the simulation, the resultant movements can be saved as a program, which can then be downloaded directly into the robot's control system.

2. SELECTED DEVICES FOR INTEGRATION

For controlling the robotic device, the CyberGlove II data glove from Immersion Corporation was selected, which features 18 motion sensors and communicates with the computer using Bluetooth technology. Its detailed technical specifications are provided in Fig. 1.

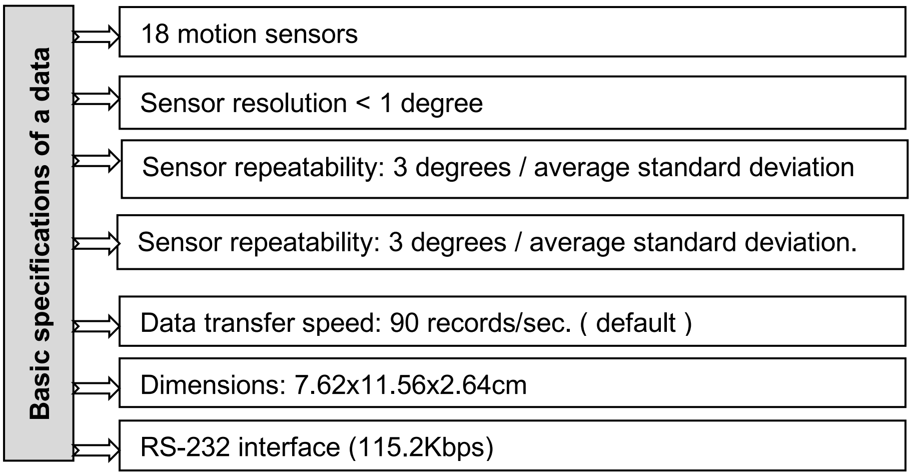

Fig. 1. Technical specifications of the CyberGlove II data glove.

The CyberGlove II is equipped with Bluetooth wireless technology and is powered by its own energy source. It features 18 sensors that accurately record and monitor the movements of the human hand. These movements are then converted into signals that control a robotic hand connected to the Cyberglove2 RoboticHand program. The glove itself is made from flexible fabric, ensuring comfortable fitting and wear. The connection to the power source is shown in Fig. 2, allowing for continuous operation without the need for wired connections. This solution enhances interaction with robotic systems and increases efficiency in practice.

Fig.2. CyberGlove II Data Glove

As a robotic device for verifying the functionality of the software, a model of a robotic hand created in a CAD system was selected, including the specification of relevant requirements and manufactured using additive technology. In the CAD system, individual construction components and elements of the relevant product group are also modeled and verified. The solution uses the generic concept of hierarchical decomposition of the modeled product group as a fundamental principle. In designing the robotic hand, attention was paid to functionality and design, which is intended to resemble a human hand. This was especially adapted for the fingers and the contact part of the palm. A two-segment variant was chosen for modeling the fingers, which is sufficient for grasping objects. The physical model of the robotic hand is shown in Fig. 3.

Fig. 3. Complete part of the robotic hand

3. DEVELOPMENT OF CUSTOM SOFTWARE FOR DEVICE INTERCONNECTION

For effective interconnection and synchronization of the data glove with the robotic system, custom software was developed at the Department of Industrial and Digital Engineering, Cyberglove 2 RoboticHand, written in the C++ programming language. This software allows for precise control of the robotic system through the data glove. It enables detailed calibration of individual servo motors, which includes setting the sensitivity and range of their movements, thereby providing the user with a high degree of control over the movements of robotic devices. The software offers the possibility of independently setting each finger, with each finger equipped with sensors located on the first and second joints of the data glove, reflecting the degrees of freedom of the robotic hand. Each sensor can be individually calibrated, allowing for customization of the movement range and sensitivity according to user needs. Fig. 4 shows the interface and method of setting these motion sensors for the Cyberglove2 data glove, providing a clear overview of its configuration options. [2]

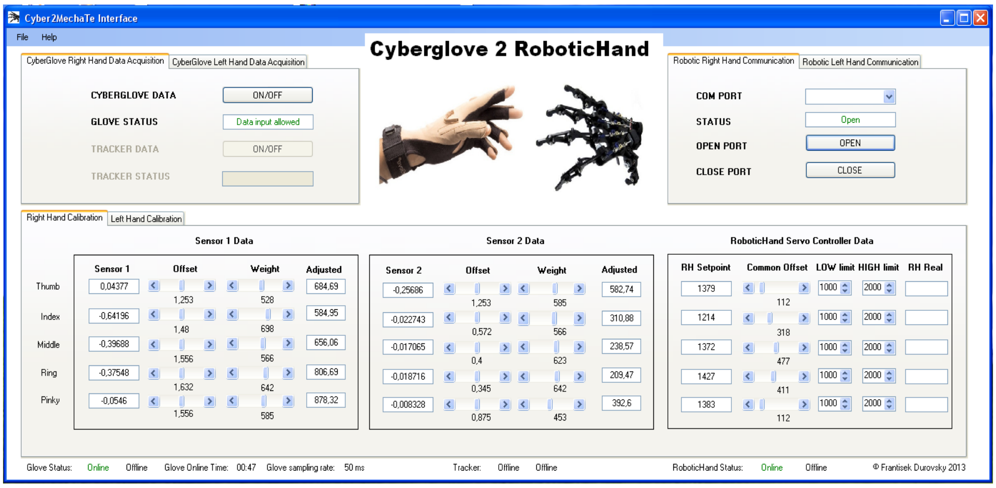

Fig. 4. Cyberglove 2 RoboticHand Software Environment [2]

Fig. 5 shows the calibration of the servomotors of the robotic hand. It is also possible to set each servomotor of the robotic hand individually and synchronize them with the CyberGlove II data glove.

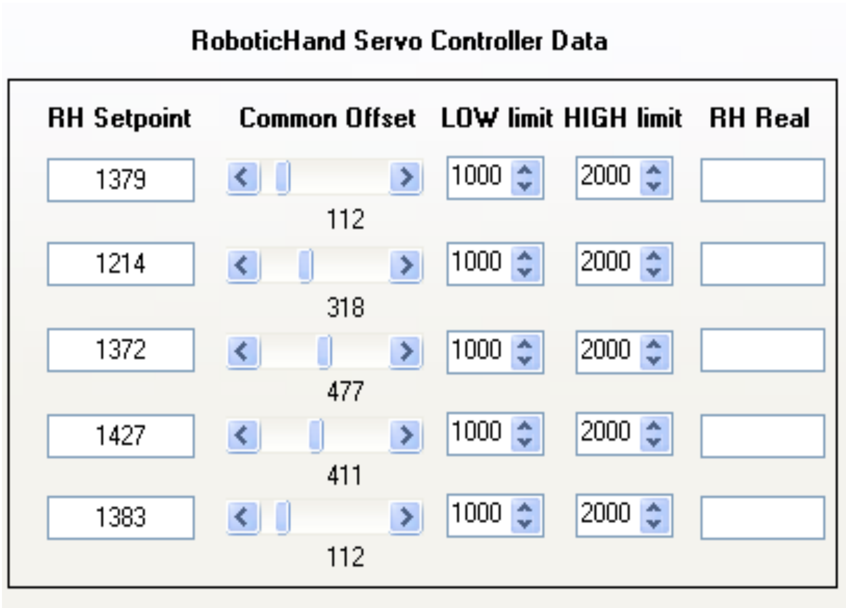

Fig. 5. Calibration of Servomotors of the Robotic Hand [2]

Fig. 6 shows a section of the code from the Robotic Hand program, which is used to set the sensitivity of the sensors on the glove and the operation of the software.

```
sensor_R_thumb2 = glove->getData((GHM::Fingers) 0, (GHM::Joints) 2);
//
sensor_R_index1 = glove->getData((GHM::Fingers) 1, (GHM::Joints) 1);
sensor_R_index2 = glove->getData((GHM::Fingers) 1, (GHM::Joints) 2);
//
sensor_R_middle1 = glove->getData((GHM::Fingers) 2, (GHM::Joints) 1);
sensor_R_middle2 = glove->getData((GHM::Fingers) 2, (GHM::Joints) 2);
//
sensor_R_ring1 = glove->getData((GHM::Fingers) 3, (GHM::Joints) 1);
sensor_R_ring2 = glove->getData((GHM::Fingers) 3, (GHM::Joints) 2);

sensor_R_pinky1 = glove->getData((GHM::Fingers) 4, (GHM::Joints) 1);
sensor_R_pinky2 = glove->getData((GHM::Fingers) 4, (GHM::Joints) 2);

glove_time = glove->getLastUpdateTime()-glove_base_time;
glove_time = System::Math::Round(glove_time,0);
```

Fig. 6 Section of the Cyberglove2 RoboticHand Software Code

4. UTILIZATION OF THE INTEGRATED ROBOTIC SYSTEM

The integrated system, which combines the use of a data glove with a robotic system, is primarily utilized in the assembly and disassembly processes of components. In practice, this means that the operator performs individual actions using the data glove, while the robotic system synchronously repeats these actions. This procedure not only significantly saves labor but also enhances and automates processes in assembly halls. For the system to achieve optimal efficiency, it needs to be further expanded with additional components, such as joints, bearings, and various types of sensors. These components will be integrated into the system in further development, allowing even more precise and flexible control of robotic mechanisms, thereby increasing overall productivity and safety of the work process.

Fig. 7. Synchronization of Movements between the Data Glove and the Robotic Hand

The control and gripping capabilities of the system were tested on objects of various shapes and structures. Precise synchronization tuning between the robotic hand and the data glove was necessary to ensure real-time feedback between the glove and the robotic hand. An object was presented to the robotic hand and then grasped using a simulation of grip performed with the data glove worn by the operator. For each object, it was necessary to find the most suitable method of grip to prevent the object from falling out of the robotic hand. Examples from experimental laboratory testing are shown in Fig. 8.

Fig. 8 Simulation of Gripping a Physical Object [4]

5. CONCLUSION

Virtual technologies, already an important driving force in technology today, open up new application areas that will significantly change human life. The growing digitization and virtualization of production lead to significant changes in existing industrial and manufacturing technologies. In the industry, and especially in manufacturing, the integration of the real and virtual worlds is increasingly taking place. There is an increasing share of advanced industrial automation not only in production but also in all spheres of human activity. The system of knowledge and methodological procedures gained from experiments with the integration of the data glove and robotic hand highlights the significant potential for its use. Its application is anticipated in various areas of industry and services. The progress being recorded in the development of technical and software resources significantly affects the previously customary work methods and procedures applied in robotics. The results of the study of the issues and experiments conducted in laboratory conditions highlight a significant application area for virtual technology, which can be used both in robotics, assembly, disassembly of components in handling processes, and in other issues.

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CHANGE OF COMPETENCIES IN THE LABOUR MARKET IN THE CONTEXT OF INDUSTRY X.0 PRINCIPLES

Abstract

In the current era of dynamic technological change and innovation in industry, the structure of the labour market is also undergoing fundamental changes, affecting both the jobs themselves and the competencies required of employees. This paper focuses on how the transitions through the different industrial revolutions have impacted on the structure of jobs. Using exact methods, we will be able to create the necessary set of competencies and prioritize the competencies needed for specific employee positions based on the job description.

Key words: Competencies, Change, Industry x.0, Exact methods

1. INTRODUCTION

Technological innovations such as artificial intelligence (AI), the Internet of Things (IoT) and automation are playing a significant role in changing the labour market. These changes can be described as Industry x.0, which includes the progression from Indsutry 4.0 to Indsutry 6.0. Changes in industry have transformed not only manufacturing processes, but also the structure and character of jobs. Industry x.0 represents a next step forward, where digitalisation and automation are impacting almost all aspects of work life. The aim of this paper is to explore how these advances in technology affect the competency requirements of employees, what specific competencies are and will be needed. The importance of the issue discussed lies within its impact on the education of employees, even potential employees, and the overall preparation of the human workforce for future challenges.

1.1 From Industry 4.0 to Industry 6.0

In the last decade, the concept of Industry 4.0 has been globally emerging and recognised, which is mainly known for technological innovations in the sphere of automation and digitalisation. It can be understood as a change caused by new

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professionals who would be able to put the elements of the Industry philosophy into practice. The lack of competences results in a situation in which local enterprises are not able to sufficiently finance significant changes and innovations in their manufacturing processes to bring their manufacturing level in line with the principles of Industry 4.0. [2]

Eleven years later, after the Fourth Industrial Revolution, the term Industry 5.0 was introduced, which is value-driven. Industry 5.0 is a concept whose emergence seeks to complement Industry 4.0 technologies by adding an focus on environmental, human and social value. [3] By putting employee well-being and green production first for I5.0, the industry becomes more sustainable in this era than before. It is a era when humans and machines have started to work together to create a human-technology interaction, bringing together the benefits of Indsutry 4.0 with the human touch. The aim is to create a working environment where, in human-machine work, machines perform routine, repetitive tasks that can be dangerous, while humans can engage in creative, even if more complex, work. This approach to work can have a positive effect on productivity, employee satisfaction, as well as promoting social responsibility and sustainability. [1,4]

Industry 6.0 is a synergy of ideas that is the creation by the millions of minds of scientists, researchers, leaders and predictors. Indsutry 6.0 is one step more advanced than the previous two industrial revolutions. All operations would be controlled by human minds while being transformed by automated robots. This new version of Industry combines human intelligence with artificial intelligence, cloud computing energy or human-machine cooperation with Big Data. [5]

1.2 Changes in the structure of jobs – identification of future needs and competences

Today, the market situation is currently marked by turbulent developments and is facing many new challenges and changes that automation, digitalisation, robotics and artificial intelligence have brought. With the advent of Industry philosophies, there is an upheaval in the job structure, with certain jobs disappearing but being replaced by new ones. The demand for labour and the requirements placed on employees are also changing, increasing the pressure on educational institutions to prepare students who will be employable in practice and possess the necessary skills. Enterprises have to face stressful situations from the external environment, but at the same time have problems with human capital management. In the future, people who have low skills and are unable to adapt to change and learn will be particularly at risk. The advent and growth of automation threatens female-dominated professions, such as sales, office or administration. [6]

According to the study "Technological Forecasting and Social Change" (Frey, Osborne), it can be argued that the jobs of people in transport and logistics, office and administrative support employees, as well as people working in manufacturing professions will be at risk. Their work is likely to be replaced by computer capital, as the development of computer-equipped cars is under way and the price of sensors is falling, making their production more efficient than before. Algorithms for analysing big data are becoming more and more widespread, so work in administration and the office will also be subject to informatisation. Industrial robots are becoming more advanced, with better senses and skills, and will eventually be able to perform a wider range of non-routine manual tasks, and will therefore replace employees in manufacturing. In terms of technological advances and developments, it can be argued that in the coming decades, the most significant employment reductions will be in manufacturing professions. [7]

2. METHODS AND METHODOLOGY

The aim of the research is to realize bibliographic analysis of scientific publications in indexed databases using VOSviewer. It is a software for visualization and analysis of bibliographic data. It is used in academic research to analyze scientific publications and their connections. It allows you to create visualizations of scientific data, such as citation networks, which show the interconnections between authors, research topics, institutions and publications based on cross-citation. These visualizations can provide insights into the structure of the scientific community, identify key authors and institutions, detect trends in the scientific literature, and identify areas of research that are connected or isolated from others, tracking and understanding temporal trends and dynamics in the research environment. The term map created using this software is a map of the central terms in the area of the paper's problem area. The map shows the key terms connected by lines based on their interconnections and contexts. The occurrence of each term can be read from the size of the circle that appears next to the term. The colour differentiation used for the circles marking the terms is based on the occurrence over the years, i.e. when the term first appeared in publications published in databases such as Web of Science or Scopus.

An appropriate follow-up to the research after the bibliometric analysis may be the application of the AHP method, which through expert estimates can confirm or negate the results and outcomes obtained from research and scientific publications in the subject area. We foresee the use of the software in two application dimensions, namely:

- The assessment of employee competences in selected industrial enterprises.
- In the creation of competence profiles in selected industrial enterprises.

The determination of the decision-making objective is the creation of the necessary set of competencies of line managers in industrial enterprises.

Proposed solution options: the solution alternatives are presented by the line managers themselves in industrial enterprises in different sectors of industry.

Proposal of criteria for the evaluation of the solution options: the set of competences will be created on the basis of the criteria specified in the job description of the line managers, which will be collected in the proportion as the share of the individual supporting segments of industry in Slovakia.

On the basis of the job descriptions, generally the same work activities related to the performance of the analysed positions will be identified, to which the necessary competences will be assigned. In addition to the above criteria for the present, criteria will be added according to analyses and forecasts for the next 5 years (see [9]).

The resulting set of competences (competence profile) will be the basis for the development of existing competences and for the retraining of missing competences so that small and medium enterprises will be able to compete in a competitive environment and their line management will be prepared to face the challenges arising from the implementation and application of the principles of Industry x.0.

3. RESULTS AND DISCUSSION

The vision of Industry 4.0 will therefore have a major impact on the skills required in the labour market. The need to consider their social impact will become a necessity. These impacts will lead to new principles of work organisation, from changing the employer's role, to changes in the structure and skills that will be in the job description of most professions, which will be completely changed, and there will be impacts on the development of employment and unemployment, which will require a new policy framework for the labour market and education. [8]
In the next five years, 83 million jobs are projected to be lost and 69 million jobs are projected to be created, constituting a structural change in the labour market of 152 million jobs, or 23% of the 673 million employees in the data set studied. This constitutes a reduction in employment of 14 million jobs, i.e. 2%. [9]

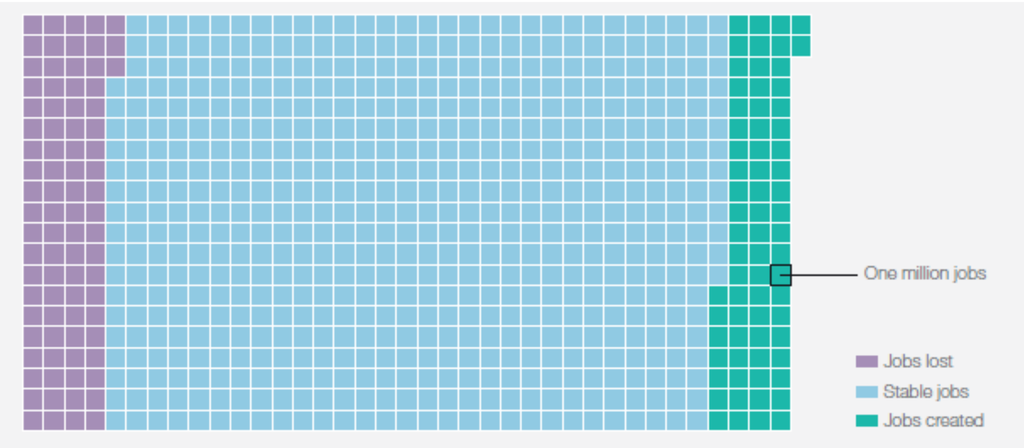

Fig. 1. Projected job creation and displacement 2023 – 2027 ([9], p. 28)

Since Slovakia is significantly behind other, more industrialized countries in the digital skills of its employees, the only way forward is to strengthen education and training of employees. These educational activities should be directed towards the acquisition of new, necessary and missing competences that employees/managers will need in the future to perform their work. However, emphasis should also be placed on ensuring that employees have a proper understanding of the relevance and contribution of Industry concepts to their work life, as they resist change and the development of their own skills for fear of losing their jobs.

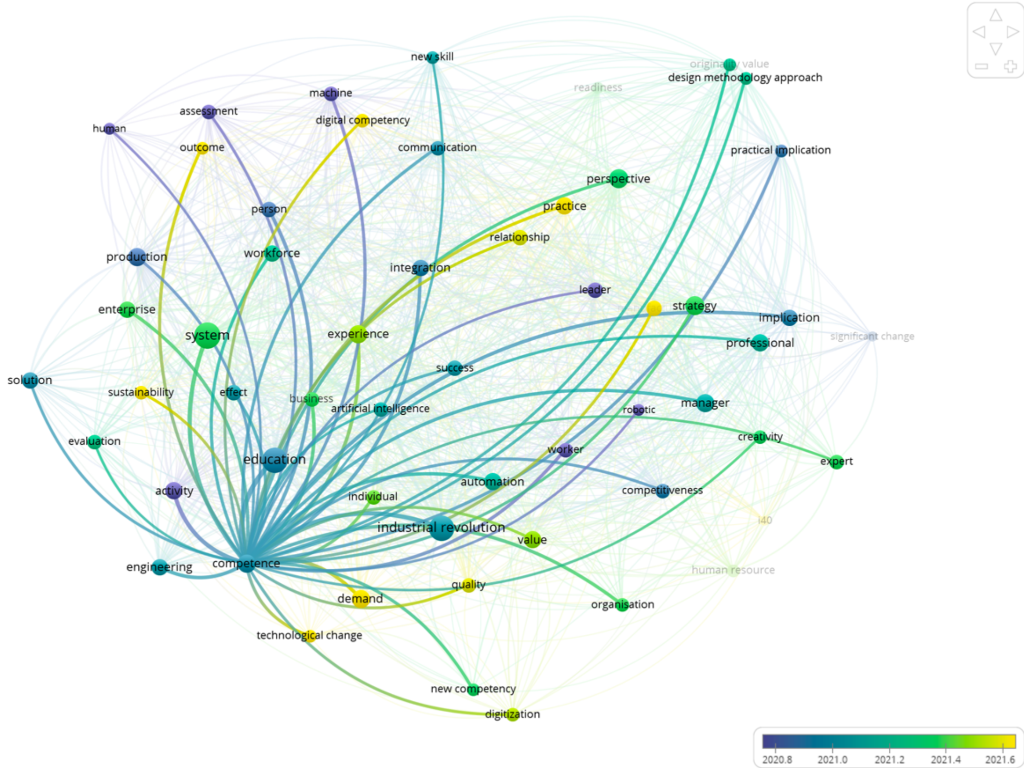

Fig. 2. Graphical illustration of the bibliometric analysis of the research topics and their relations to each other in the publication outputs registered in the Web of Science (VOSviewer, 2024)

Fig. 2 shows a term map based on publications from the WOS database that were found in association with the keywords "Industry x.0", "change" and "competencies".
From the bibliometric analysis focusing on the linking of Industry x.0, change related to implementation linked to the competencies area, we can deduce that industrial enterprises are aware of the importance and necessity of changes related to employee competencies, development and education when integrating Industry philosophies into their conditions.

4. CONCLUSION

Enterprises gain competitive advantage and differentiation from other enterprises within the industry through human capital. It is therefore more than necessary for enterprises to continuously educate their employees and develop their competences. Getting a 'ready-made' manager who has the right skills, abilities and knowledge is a challenge nowadays, as every enterprise tries to attract only the best employees to ensure that the enterprise continues to move forward and does not stagnate in terms of performance, for the reasons of sustainable competitiveness.
The competency profiles forming the output of scientific research should be flexible, adaptable and, even if new elements of Industry x.0 were to be further introduced, enterprises would only assign the required skills to master the new activities to

the competency profiles they have created. However, in order for employees to perform at a high level that corresponds to a managerial position, they must have the prerequisites, the work behaviour, but first and foremost the proved and identified competencies. The competency profiles that will be created through the use of the AHP method can also be further used in the selection, development, management or rewarding of employees.

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APPLICATION OF THE LASSO REGRESSION METHOD TO THE SELECTION OF BANKRUPTCY PREDICTION CHARACTERISTICS

Abstract

The goal of the article is the application of the Lasso regression method to select characteristics suitable for predicting the financial health of companies. The article is divided into 3 parts. The literature review provides an overview of approaches to selecting a sample of financial data used to predict bankruptcy. In the Methods and discussion section, the Lasso regression method is described, which shows a high predictive power. The third part of the work presents the results of the application of the selected method to a sample of 351 companies operating in the automotive industry in the territory of the Slovak Republic. The output is a list of financial and accounting indicators that have a significant impact on assessing the financial health of companies operating in the automotive industry.

Key words: Financial indicators, Lasso regression, Prediction of bankruptcy

1. INTRODUCTION

The topic of analysis and prediction of financial health has been addressed by a number of authors in various scientific studies since the 1930s of the last centuries with the aim of creating a method that will predict with the greatest accuracy and with sufficient advance the possibility of decline and bankruptcy of a company. The methods are based on the assumption that exist certain anomalies or signals that can be observed in the values of financial indicators even before the threat of bankruptcy. An important step in predicting the financial health of companies is, for the reason, the selection of appropriate input characteristics. We will deal with this issue in the presented article.

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2. LITERATURE REVIEW

An important step that will increase the predictive ability of the model is the selection of a representative data sample. Financial indicators for previous periods are used to assess the financial health of companies. Not all financial indicators have the same explanatory power, and the use of all basic ratio indicators to evaluate the financial health of companies is considered biased. There is no generally valid method of selecting financial characteristics. In practice, two approaches to the selection of financial or accounting indicators. The first approach is the "domain knowledge" approach, whose main representatives are Altman (1968), Springate (1978), Zmijewski (1984), Lee et al. (2002), Hu (2009), Tsai and Hsu (2013). Authors Lin et al. (2014), Zhou et al. (2015) used the "domain knowledge" method and the results obtained by data mining methods, where the application of genetic algorithms proved successful. Bellovary et al. (2007) in addition to classic bankruptcy prediction indicators, they also focused on characteristics reflecting central bank policy and non-financial indicators (e.g. presence of government control, state economic sanctions, market share, Tian et al. in 2015 used the Lasso method to select characteristics and the results reached In the presented article, we will focus on the application of the Lasso method for predicting the financial health of companies:
SK NACE C – Industrial production:
29 – Manufacture of motor vehicles, semi-trailers and trailers
29.1 Production of motor vehicles
29.2 Manufacture of bodies for motor vehicles; production of semi-trailers and trailers
29.3 Production of parts and accessories for motor vehicles
    29.31 Manufacture of electrical and electronic devices for motor vehicles
    29.32 Manufacture of other parts and accessories for motor vehicles.
The database of financial statements was obtained from the Universal Register CRIBIS from the company CRIF – Slovak Credit Bureau, s.r.o.

3. METHODS AND DISCUSSION

Lasso regression belongs to the most famous methods from the group of so-called regularization methods. It is one of the regression analyses, which carries out the selection of variables and the regularization of coefficients in order to achieve more accurate estimates (Fahrmeir, Kneib 2017). LASSO (Least Absolute Shrinkage and Selection Operator) regression uses the method of least squares and adds a penalty constant λ. The penalty is influenced by the size of the coefficient λ , which is calculated according to the minimum prediction error during cross-validation, denoted λmin. Lasso regression has a good predictive ability because it is able to decrease the regression coefficients towards zero (Fonti, Belitser 2017). Using the LASSO method has many advantages, first of all, it can provide very good prediction accuracy because the removed coefficients can reduce the variance without significantly increasing the deviation, which is especially useful when we have a small number of observations and a large number of variables. In addition, LASSO helps to increase the interpretability of the model by removing irrelevant variables (Hastie, Tibshirani, Friedamn 2009). In the case of logistic regression, the penalized logarithmic function has the following form (Fahrmeir, Kneib 2017):

$$\min_{\beta \in R_p} \sum_{i=1}^{n} \left(Y_i - \sum_{j=1}^{p} x_{i,j}\beta_j\right)^2 + \lambda \sum_{j=1}^{p} |\beta_j| \quad (1)$$

where λ ≥ 0 is the parameter.

4. RESULTS

To assess the financial health of the selected companies, 20 financial indicators were applied, from which significant financial indicators will be selected using the Lasso regression method. The optimal value of the penalty constant λ was chosen according to the minimum prediction error of the model λmin, which is located at the lowest point of the curve shown in Fig.1.

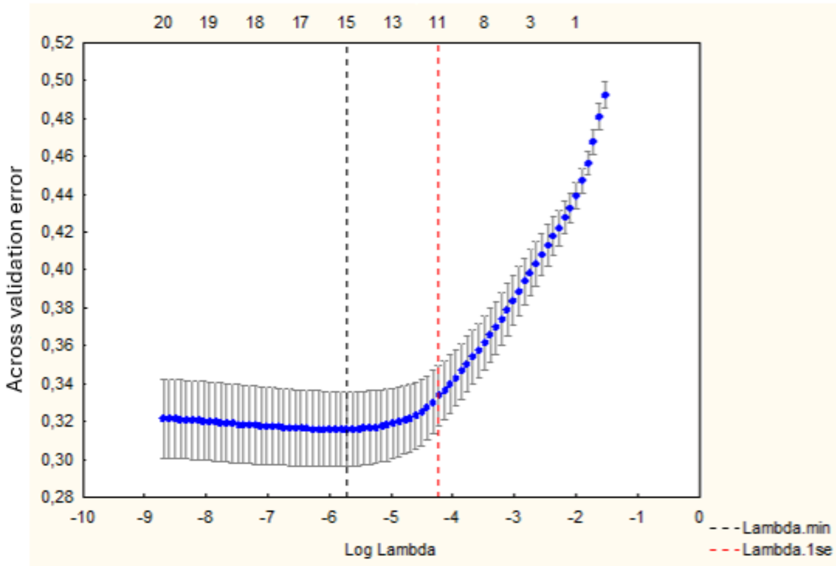

Fig. 1. A cross-validation error depending on lambda

On the Fig. 2 are illustrated coefficients of indicators depending on lambda.

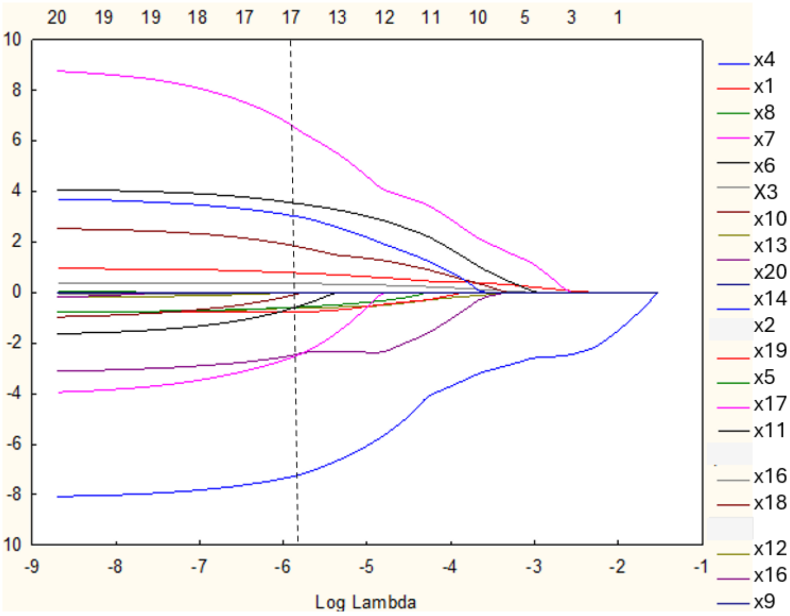

Fig. 2. Coefficients of indicators depending on lambda

The values of the coefficients of individual indicators depending on **λ_{min}** are shown in the Tab. 1. From the input indicators using LASSO regression, their number was reduced to the number of 13 indicators with a non-zero value (Tab. 1). Coefficients with a value close to 0 are discarded and considered less significant.

Tab.1 Coefficients for **λ_{min}**

Sign	**Indicators**	**Model Lambda = 0,00329;** Coefficients
	Constant	2,77465
x_8	Liquidity II. degree	
x_1	Liquidity III. degree	0,75647
x_9	Stock turnover time	
x_{10}	Maturity period of receivables	1,74586
x_{11}	Maturity period of short-term receivables	-0,43376
x_{12}	Maturity period of obligations	
x_2	Maturity period of short-term liabilities	2,93061
x_3	Asset turnover	0,353950
x_4	Total indebtedness of assets	-7,12882
x_5	Equity to liabilities ratio	-0,55866
x_6	Long-term indebtedness of assets	3,46935
x_{13}	Credit indebtedness of assets	-0,59116
x_{14}	Interest coverage	0,00055
x_{15}	Current indebtedness	

Tab. 1 Coefficients for λmin (continuation)

x_{16}	Return on equity	-0,00061
x_7	Return on assets - gross	6,22307
x_{17}	Operating rentatability of sales	-2,32028
x_{18}	Share of newly created value in sales	
x_{19}	Share of added value in sales	-0,76586
x_{20}	Share of EBITDA in sales	-2,36252

Based on the data presented in Tab. 1 and shown in Fig. 2, we can conclude that the following indicators can be considered significant indicators: liquidity III. degree, maturity period of receivables, maturity period of short-term receivables, maturity period of short-term liabilities, asset turnover, total asset indebtedness, long-term asset indebtedness, asset credit indebtedness, profitability of assets, profitability of sales, share of added value in sales and share of EBITDA in sales. We consider coefficients that are close to 0 to be less significant, so we excluded them. It is an indicator of interest coverage and return on equity. The LASSO regression method has the ability to select only one variable from variables that are highly correlated with each other, while the other variables are discarded, so there is no need to perform further analysis of the input variables, and we consider the output of the LASSO regression as the input indicators for the logistic regression.

5. CONCLUSION

Most business entities are founded with the aim of bringing benefits to their owners with an unlimited lifetime of the business. Under the influence of the turbulent development of the economic and political situation, they often fail.

Failures of business entities can have various manifestations and consequences. The consequences are the foundation for further research and development of prediction methods and models that can predict the development of the financial situation and the probability of bankruptcy or bankruptcy with high accuracy and sufficient lead time.

For this reason, it is necessary to pay due attention to the selection of suitable financial indicators, so that the resulting predictive ability is as high as possible. The Lasso regression method was used to select significant financial indicators, the advantage of which is that it selects one variable from indicators that correlate with each other. Based on the Lasso regression, 13 indicators are considered significant from the 20 financial indicators assessed at the entrance on prediction of financial healthy.

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THE IMPACT OF WORKPLACE NOISE ON THE HUMAN PSYCHE

Abstract

The presence of excessive noise in the workplace has a negative impact on hearing, which is widely known. However, noise itself can also have a negative impact on the psychological well-being of employees, leading to increased psychological strain. This article discusses the effects of workplace noise on employees' psychological well-being and the increase in psychological stress.

Key words: Noise, Work stress, Health

1. INTRODUCTION

Psychological stress has become one of the most monitored factors of working life in recent years, as the number of stress-related disorders and diseases is increasing. The human psyche is affected by various factors, not only in everyday life but also in the work environment. These factors include, for example, dust, heat, various odors or noise [1].
It is noise that can be one of the triggers of psychological problems. It can be described as a ubiquitous environmental stressor that has negative effects primarily on hearing, but research also shows a negative impact on the psyche. Prolonged exposure to excessive, can act as a psychological stressor and therefore increases the psychological burden on the employee. A single exposure to very high noise levels also leads to hearing loss (acoustic trauma), which in turn has a negative impact on the psyche [2].

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2. LITERATURE REVIEW

The effects of excessive noise on the human body are well established and well known. Repeated exposure to noise levels of 85 dBA and above causes tinnitus, hearing impairment and can lead to complete hearing loss. However, noise also has extra-auditory effects on the body, including cardiovascular diseases such as hypertension, cardiac arrhythmias, balance problems, sleep disorders and depression. There has also been a weaker and less consistent link between noise pollution and elevated cholesterol levels. The presence of noise in the workplace can also directly affect worker performance and the quality of work performed, depending on the type of work performed [3, 4].

2.1 Development of noise-induced hearing impairment at the workplace in Slovakia

The primary area of the body that is affected by excessive noise is the ear and hearing. As shown in Fig. 1, over a 20-year period, the number of recognized hearing impairments from noise in the workplace has had a fluctuating trend. In recent years, as of 2019, the number has stabilized below 20 cases per year, which is a positive result compared to 2001, when the number of cases was 47, indicating a decreasing trend [5].

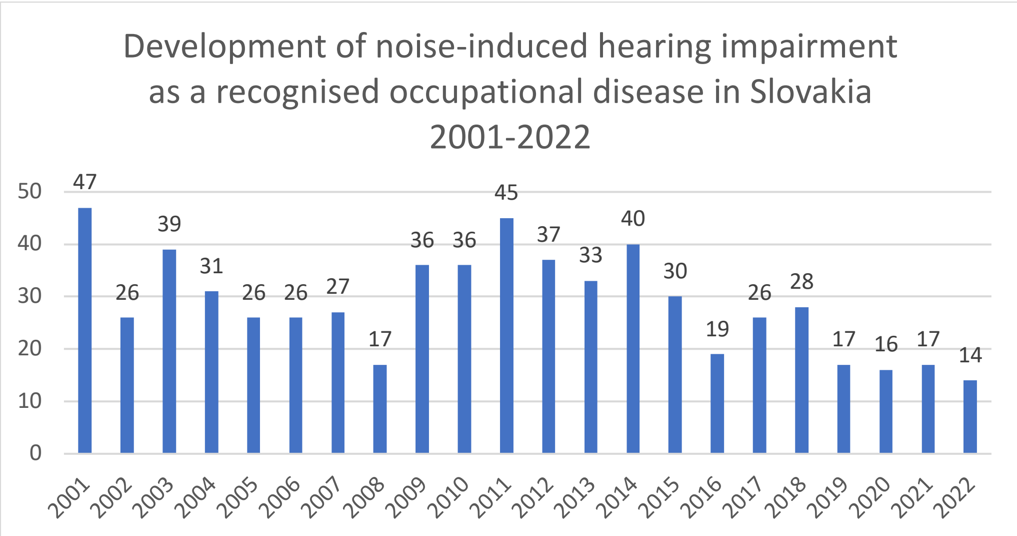

Fig. 1. Development of noise-induced hearing impairment as a recognized occupational disease in Slovakia 2001-2022.

In addition to these diseases, which are primarily noise-induced and are manifested by impaired or complete loss of hearing function, noise itself contributes to the development of many other diseases.

2.2 Impact of workplace noise on psychological distress

Although noise is a ubiquitous factor and it is difficult to isolate the effects of noise in the workplace on the human body, it is necessary that research is devoted to this issue to help detect risks and implement appropriate preventive measures.

Although some researchers argue that noise exposure is not a valid indicator of mental health outcomes, other research points to some link between this factor and the psyche. It is clear that noise is not the sole and definite cause of psychological distress, but its influence cannot be ruled out [6].

Research shows that noise not only has a negative impact on hearing, but also contributes, among other things, to psychological discomfort, resulting in an overall impact on increased psychological strain at work. A collective of authors [4] states that the effect of noise on stress has been studied many times and it has been shown that the presence of noise can induce restlessness, exhaustion, depression, increased sympathetic tone or stomach upset in humans as a result of the presence of stress [4].

According to the authors [2], a link between noise and physiological stress has been demonstrated. The basic biological mechanism of action of high levels of noise has been proven, based on the stimulation of physiological arousal through the activation of the endocrine system and the autonomic nervous system, resulting in an increase in the level of stress hormones. [2]

The theory of the effect of noise on hormonal regulation is also supported by another publication [7]. Other authors dealing with this issue describe an interactive stress model that explains how noise-induced psychological stress contributes to cardiovascular, respiratory and metabolic disease risks. Repeated or frequent stress thus induced throws the body out of homeostasis and triggers a cascade of physiological reactions. Elevated concentrations of stress hormones have been observed in many studies investigating the effects of noise [7].

A research team in China has also looked at the link between occupational noise and mental health [1]. The authors highlight the need to distinguish between subjectively perceived noise and objectively measured noise. This is because perceived noise has a more widespread negative impact on mental health compared to measured noise. This points to the individuality of each person, which needs to be taken into account in research, especially when it comes to psychological perception and stress. The level of perceived noise is influenced by many factors, such as gender, age, level of education or occupation, indicating individual differences in noise sensitivity and psychological adaptability. As a result of the investigation, higher levels of perceived noise have been shown to be associated with an increased risk of anxiety and depression, suggesting a relationship between noise exposure and a person's psyche [1].

In order to prove the impact of a noisy environment on mental state, researchers in Malaysia [6] conducted a research where they monitored brain activity using EEG (Electroencephalography). At the same time, salivary alpha amylase activity was monitored before and immediately after performing a task. This enzyme is involved in the metabolism of carbohydrates and starches, responds to stress stimuli and increases substantially in response to them. During the research, probands performed the same type of work in a quiet environment and in a noisy environment. Subsequently, the levels of alpha amylase were observed and also the results of an EEG that was performed in the frontal area. The results of the experiment showed an increase in salivary alpha amylase levels in the noisy environment and also a decrease in cognitive activity, suggesting that noise causes an increase in stress. Fig. 2 shows a comparison of salivary alpha amylase levels in quiet and noisy environments [6].

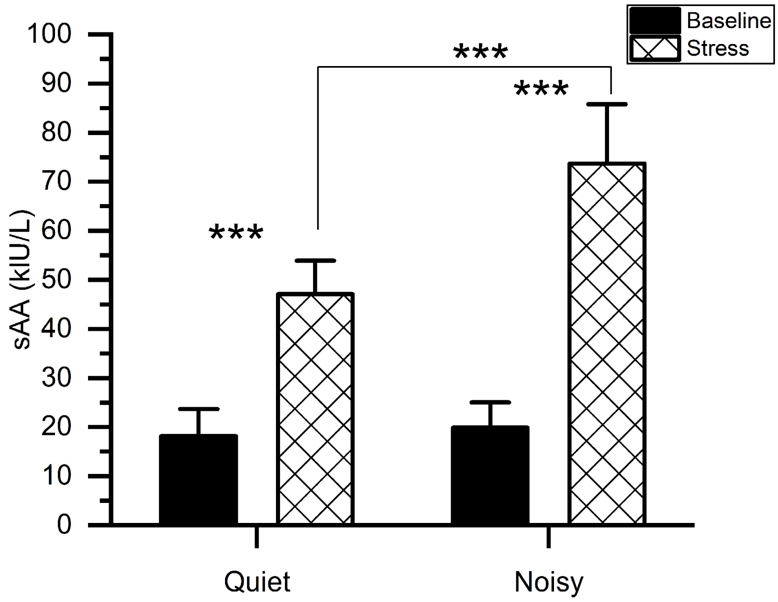

Fig. 2. Comparison of salivary alpha amylase levels when working in a quiet environment (left) and in a noisy environment (right). [6]

The impact of noise on psychological well-being has also been investigated in relation to stressors in open-office offices. During the experiment, the effects of the open-office environment were compared with those of a conventional office environment where noise levels are lower. The obtained parameters indicated a decrease in psychological well-being and an increase in stress levels due to the effects of a busy and noisy open-office environment compared to a quiet private office. In addition to the subjective opinion of the probands, objective parameters such as heart rate and skin conductance were also monitored, which increased in direct proportion to the increasing serpentine stress level. [8]

Another research [9] was based on a similar principle, comparing stress levels in two environments with different noise levels. In this case, a comparison was made between workers working in a noisy factory area and workers working in a quieter administrative area of the factory, based on their subjective perception of noise and feelings of stress. The research also showed a significant relationship between noise intensity and perceived stress level [9].

The same conclusion was reached in a study [10], in which simulation algorithms were used to study the correlation between stress and noise levels. This study highlighted the importance of using protective work equipment for hearing protection. Their application led to a reduction in the level of stress in the workplace, again showing the correlation between the presence of noise and the presence of stress [10].

The negative impact of the presence of noise in the workplace has also been reviewed in [11], which highlights the impact of noise and unsuitable working conditions on overall human health [11].

3. CONCLUSION

Noise is a ubiquitous stressor that we encounter not only in everyday life but also in the workplace. Its level and intensity varies according to the location and type of working environment and the nature of the work itself. As research shows, its impact on the human psyche is demonstrable and not insignificant. It is also important to note that everyone's perception of noise is individual and therefore its effects on the human body vary. In the same way, the contribution of exposure to excessive noise to hearing impairment or complete hearing loss is also an undeniable factor, often resulting in a limitation of working capacity and also psychological well-being.
Research has also shown the importance of using protective work equipment to protect hearing, which also prevents the impact of noise on psychological well-being.
It is clear from these findings that the impact of noise in the workplace also affects the psyche of employees and leads to an increase in psychological distress. It is therefore necessary to pay attention to further research in this area and also to call for the application of protective work equipment.

Acknowledgment

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IMPROVING THE PRODUCTION PROCESS AND INVENTORY MANAGEMENT IN THE CHANGING ORGANISATIONAL ENVIRONMENT OF SMALL BATCH PRODUCTION

Abstract

This article presents an analysis and improvement of selected areas, the development of which is part of a comprehensive approach to the implementation of new technological solutions in unit and small batch production. The purpose of the paper is the identification of best practices that can significantly contribute to the success of this process.

Key words: Simulation of production processes, Inventory management, Production process management

1. INTRODUCTION

Developing a knowledge of the challenges that companies face during the implementation of new technologies is key to successful process management.
Focusing on the organisation and management of production in a changing organisational environment, are crucial areas in the development and efficiency of business operations.
This article focuses on production planning, supply chain and resource management. Due to the production challenges that face unit and small batch production, the research focused on a medium-sized company specialising in the production of cutting tools. Studies in these areas will contribute to a better understanding of the implementation of new technologies in unit and small batch production and provide practical guidance for companies seeking to effectively explore the innovation potential in the machine tool industry.

2. LITERATURE REVIEW

Production systems are characterised by multifactoriality and dynamism. Production efficiency depends on a set of factors that change over time and are unique to each system [1]. Appropriate control and improvement of processes lead to much better results, manifested in increased productivity and reduced staff workload [2].

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The use of computer simulation is one of the methods of studying the actual conduct of industrial processes or systems [3]. It is the process of creating models of reality using computers [4], to represent the various conditions that may occur during the operation of a system in its current state in the form of a model [5]. This allows the evaluation of system parameters without the need for experiments on the real system [6], thereby preventing future failures [7]. This provides the opportunity to save the expense of prototyping and implementing corrective actions caused by wrong decisions which occur at the design stage [8].
The design of production systems must provide effective solutions to fulfil demand [9]. Controlling the flow of material and information flows, is the basis of a company's logistics processes [10]. Inventory management has a crucial role in the effective operation of many companies, regardless of size or industry. Management of current inventory is part of the company's value creation process [11]. The purpose of inventory management is to keep enough products in stock to meet customer demand, simultaneously minimising the costs associated with holding and ordering stock [12].

3. IMPROVEMENT OF PRODUCTION AND SUPPLY MANAGEMENT PROCESSES UNDER MODIFIED PRODUCTION CONDITIONS

3.1. Object of research

The area that was studied includes the production of cutting tools. The main identified challenge in the defined area was the problem of implementing a new production solution, capacity management and organisation of the material flow for the production of cutting tools. The production process for band knives includes cutting to size, welding, toothing, sharpening, setting and packaging. According to increasing customer demands, laser marking was added and the packaging process was modified. Quality control after welding and before marking operations were implemented, which increased lead times. The goal was to reduce production time by 2 hours, despite changing organisational factors.

3.2. The use of modelling and simulation in production management

To verify the correctness and completeness of the modified production system, experiments using tools for modeling and simulating production processes were performed.
At the beginning of the modeling process, key assumptions were identified using available knowledge and data. The basic model was created and organized, ensuring its clarity and correct construction. Input data was verified to avoid distortion of results, as well as work was distributed between operations evenly, making sure that simulation conditions were realistic.

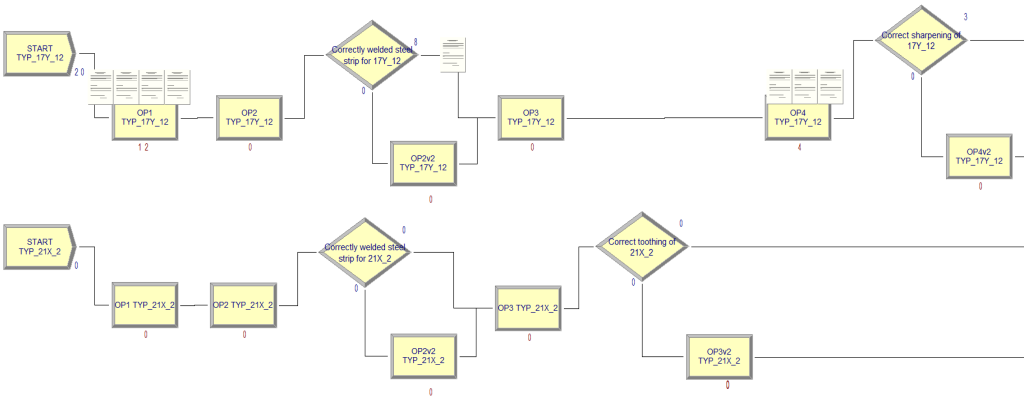

Fig. 1. Part of the base model in Arena Simulation [own elaboration].

The model was tested and verified in detail using appropriate data. The changes were made progressively, different scenarios and strategies were tested, and the results were analysed and used to adjust the model. The figure shows a comparison of the waiting times for each product before and after the changes.In the end, the lead time was reduced by more than two hours, achieving 3.19 hours.

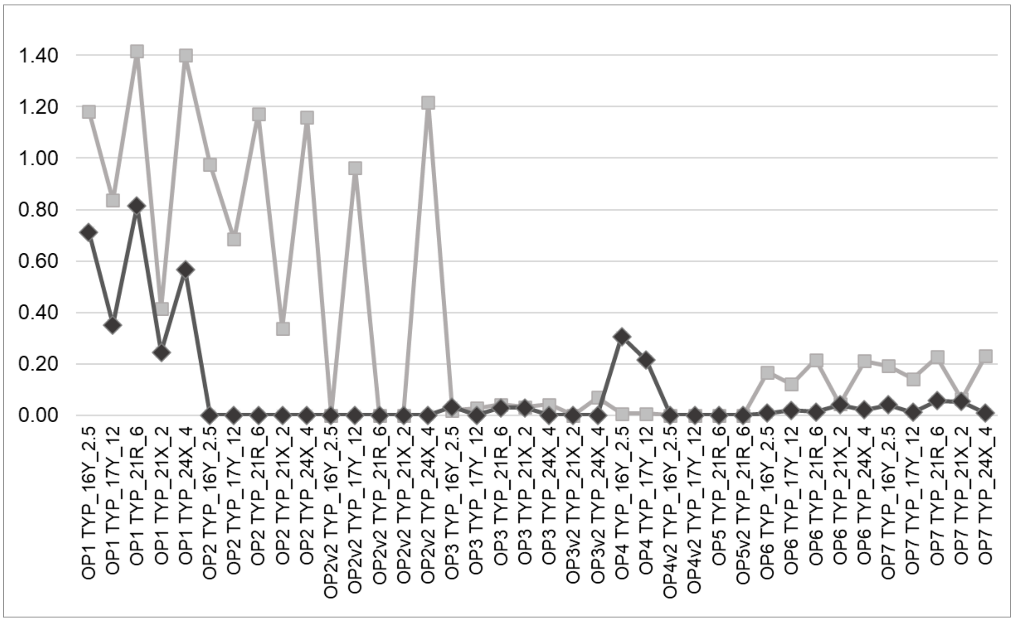

Fig. 2. Comparison of waiting times [own elaboration].

Accurate planning and defining the parameters of the production system within the production plan is helpful in maintaining balance. Observed changes indicated the need for a material inventory management policy.

The result of performing the simulation is increased planning reliability and increased compliance with cutting tool production schedules, which also helps minimize inventory. Simulation helps avoid incorrect investments in the future, thanks to the information that can be gained from the simulation. Based on the material flow simulation it can be pointed out that a properly conducted simulation process allows maximizing productivity and production capacity.

3.3. Inventory management under modified production conditions

The above research prompted the need for inventory management activities that minimize the negative impact on the reliability of the manufacturing processes. The basis for developing an effective method of material flow management in small-batch production of cutting tools was simulation for various production scenarios.
The conditions are characterized by random fluctuations in consumption and spread of delivery times, which requires the creation of stochastic inventory models. Stochastic models use statistical distributions to determine selected inventory management normatives.
The annual demand (D) for a 27x0.9mm steel strip is 3000 kg. The annual holding cost (H) is 5 EUR/kg.The cost of stock ordering (S) is on average 2000 EUR. The quantity of orders per year (Q) is one order per year for a total of 3000 kg. It was determined by observing current stock dynamics and demand forecasts. Inventory holding and ordering costs (C_{hs}) were calculated by summing the annual cost of holding inventory and the annual cost of ordering.

$$C_{hs} = \left(\frac{Q}{2}\right) H + \left(\frac{D}{Q}\right) S = 9500\ EUR \tag{1}$$

The annual inventory holding cost of 7500 EUR is higher than the stock ordering cost of 2000 EUR. Therefore, the economic order quantity (EOQ) will be less than 3000 kg.

$$EOQ = \sqrt{\frac{2DS}{H}} \approx 1550\ kg \tag{2}$$

T
hen the inventory holding and stock ordering costs (C_{hs}) are calculated for the economic order size suggested above.

$$C_{hs} = \left(\frac{Q}{2}\right) H + \left(\frac{D}{Q}\right) S = 7746\ EUR \tag{3}$$

The annual inventory holding cost of 3875 EUR is almost the same as the stock ordering cost, which is 3871 EUR in these conditions. Therefore, by ordering the appropriate level of tons of steel strip, the annual cost of maintaining inventory and ordering can be reduced by 1754 EUR.

Tab. 1. Comparison of current and expected state

	Current state	Expected state
Q	3000 kg	1550 kg
C_{hs}	9500 EUR	7746 EUR

Daily the company uses 12 kg of steel strip, which is about 63 meters ($\bar{d}$ = 12). The standard deviation of demand is 3 kg (σ_d = 3). The average lead time is 35 days ($\bar{L}$ = 35), and the standard deviation is 21 days (σ_L = 21).
According to company policy, the handling level should be 99%, meaning that the company is willing to risk that the appropriate steel strip will be missing for only 1% of the elapsed time between deliveries.
Based on the above data, it is possible to calculate the average demand over the lead time (D_{lt}), which is calculated as the product of the average monthly demand ($\bar{d}$) and the average lead time ($\bar{L}$):

$$D_{lt} = \bar{d} \cdot \bar{L} = 420\ kg \tag{4}$$

It is important to calculate the estimated demand deviation over the lead time (σ_{dL}).

$$\sigma_{dL} = \sqrt{\bar{L}\sigma_d^2 + \bar{d}^2\sigma_L^2} = 57{,}78 \tag{5}$$

To make sure that the established level of handling is maintained, the reordering point must be set high enough. The reordering point (ROP) must be within the 99th percentile of demand during the lead time. The 99th percentile for a standard normal distribution corresponds to about 2.3263 standard deviations.

$$ROP = \bar{d} \cdot \bar{L} + Z\sqrt{\bar{L}\sigma_d^2 + \bar{d}^2\sigma_L^2} = 1009\ kg \tag{6}$$

The secure stock level is equal to $Z\sqrt{\bar{L}\sigma_d^2 + \bar{d}^2\sigma_L^2}$ and is approximately 589 kg.

4. RESULTS AND DISCUSSION

Simulation of material flow allowed selective discovery of disruptive factors in existing manufacturing systems in order to systematically improve them. Through an iterative approach, the model was adapted progressively to the specific characteristics and requirements of each product, resulting in increasingly better results. In the end, the lead time under changing organizational condition. was reduced by more than two hours, reaching 3.19 hours. This allowed maximization of productivity and use of production capacity.
The capabilities of process simulation have a significant impact not only on the effective improvement of material flow, but also on inventory management, which is fundamental to the timely execution of production tasks. By reducing inventory and ordering costs, companies can improve their profitability and increase their position in the market.
The models are based on some assumptions, such as a constant level of demand or no delays in deliveries. In reality, business conditions can be more complicated, which requires adapting models to a company's specific needs and situation.

5. CONCLUSIONS

Effective inventory management can lead to cost savings, increase operational efficiency and improve a company's ability to respond to market changes. By simulating the flow of materials, companies can better adapt their production processes to changing market conditions and needs, which increases flexibility and the ability to react quickly to changes. Performing simulations allows better prediction of potential problems and risks in the production process, which enables earlier implementation of preventive measures and minimization of negative effects.
The presented approach allows planning and coordination of deliveries, which results in a lower risk of delays and production stoppages. As a result, companies can maintain production flow and deliver orders on time. It allows more precise and responsive management of resources, which contributes to better financial performance and competitiveness of companies.

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SELECTIVE LASER MELTING OF ZINC: OPTIMIZATION OF MANUFACTURING PARAMETERS

Abstract

In this study, zinc cubes were successfully fabricated using Selective Laser Melting (SLM). The Pyramis Dentas software was used to optimize process parameters, including laser energy, printing speed, density and layer thickness based on specific settings. These optimizations resulted in dense cubes with minimal porosity and good mechanical properties, underscoring the potential of SLM for producing high-quality zinc components suitable for a wide range of industrial and biomedical applications.

Key words: Selective laser melting, Zinc, Optimization

1. INTRODUCTION

Selective Laser Melting is an advanced additive manufacturing technique that uses a high-powered laser to fabricate intricate metal objects from a bed of metal powder. This study focuses on using SLM to fabricate zinc cubes, optimized through Pyramis Dentas software and fabricated using the Arrow LMP200 3D laser metal printer. During printing, the presence of zinc vapor poses challenges, including gas bubble entrapment and laser beam scattering. This article outlines our methodology, discusses observed challenges, and presents density measurement results. Through this analysis, we aim to enhance the reliability and quality of 3D printed metal parts [1,2].

2. SELECTIVE LASER MELTING (SLM)

Selective Laser Melting is an additive manufacturing technique that creates intricate metal objects from a bed of metal powder using a high-powered laser. It offers design flexibility, material versatility, and dense, durable parts [2,3].
Before SLM starts 3D printing, 3D printer must slice a 3D model into thin layers and generates 2D cross-sections that define the geometry of each layer. Inside a chamber with an inert gas, thin layers of metal powder are spread evenly across a platform using a recoating mechanism [4,5].

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A high-powered laser beam, usually an ytterbium fiber laser, selectively melts the powder particles according to the 2D slice information. The laser beam scans across the powder bed in the X and Y directions, melting the desired pattern and fusing the particles together to form a solid structure. This process is repeated layer by layer until the entire 3D object is complete [6,7].

3. METHODS AND METHODOLOGY

This section describes the equipment, materials and software Pyramis dentas used to fabricate Zn implants via Selective Laser Melting. It covers the selection of materials, optimization of printing parameters and design of prototype cubes to evaluate the feasibility of SLM for zinc processing.

3.1 Arrow 3D laser metal printer LMP200

The Arrow LMP200, a 3D laser metal printer developed by Dentas, offers a versatile and user-friendly platform for fabricating complex metal implants with high precision and design flexibility. It is designed specifically for applications in dental and orthopedic prosthetics, the LMP200 addresses the limitations of conventional SLM systems by offering compatibility with a wider range of metal powders, including those susceptible to oxidation [8,9].

3.2 Zinc (Zn) Micron Powder

Specifically, Zinc Micron Powder produced by Nanografi Tano Technology boasts a high purity of 99.9% and size of 15-53 µm, labelled as NG10MPW1305. Additionally, the particles are spherical in shape. This spherical shape offers many advantages, for example better flow characteristics and packing density compared to irregularly shaped particles [10,11].

3.3 Prototype cube design in the Pyramis dentas program

Pyramis Dentas software is ideal for creating prototype cubes due to its seamless compatibility with various 3D printing technologies. Notably, Selective Laser Melting used for metal prototypes, is fully supported too. A simple and intuitive interface provided by Pyramis Dentas is making cube design and software navigation effortless.

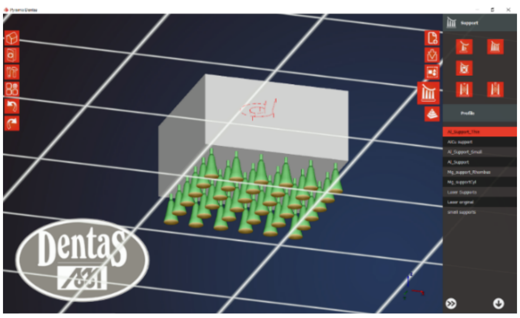

Fig. 1. Prototype cube design in the Pyramis dentas program

Optimal printing parameters can be automatically set by Pyramis Dentas based on the chosen technology and material. This ensures a good starting point for the printing process. While automatic settings are provided, Pyramis Dentas allows experienced users to adjust parameters for fine-tuning the printing process specific to the unique design of the cube. For instance, we can import a modeled cube from SolidWorks into Pyramis Dentas, seamlessly integrating the design with the software for further refinement and preparation for 3D printing. In the Fig. 1 there can be seen prototype cube with its support structure. In the Tab. 1 there are general settings for printing the cube. In the Tab. 2 there are settings for laser.

Tab. 1. General settings for printing Zn Layer

Layer height (mm)	0.0350
Support hatching	No
Skip One Layer	No
Number of internal offsetted contours	9.0000
Number of external offsetted contours	0.0000
Enable top and bottom hatching	Yes
Bottom Layer number	10.0000
Top layer number	10.0000
Overlapping Pins Label	No
Main Fill Type	Square
Hatching distance from Main contour (mm)	0.2000
Hatching angle (degrees)	4.0000
Hatching pitch (mm)	0.0500
Mono Directional Hatching Path	No
Perpendicular double filling	No
Main contour offset (mm)	0.0500
Internal contour Number	3.0000
Internal contour offset (mm)	0.0500
Overlapping Pins Label	No

Tab. 2. Laser settings for printing Zn Layer

Order	Laser Paths Order	Speed (mm/s)	Power	Hatching pitch (mm)
1.	Supports	800.0000	80.0000	0.0500
2.	Contours/Main	800.0000	80.0000	0.0500
3.	Contours/Following	800.0000	80.0000	0.0500
4.	Main Fill	800.0000	80.0000	0.0500
5.	Bottom Fill	800.0000	80.0000	0.0500
6.	Top Fill	800.0000	80.0000	0.0500

3.4 Realization of the cube prototype

In this section, the 3D printed samples of zinc cubes are presented, showcasing the successful execution of the prototype. As seen in the Fig. 2, there are 8 cubes, two sets labelled 1 to 4 with the same size. These cubes were created using advanced 3D printing techniques, demonstrating the precision and reliability of the process in producing high-quality metal prototypes. By providing the correct parameters, these cubes were successfully created to exact specifications.

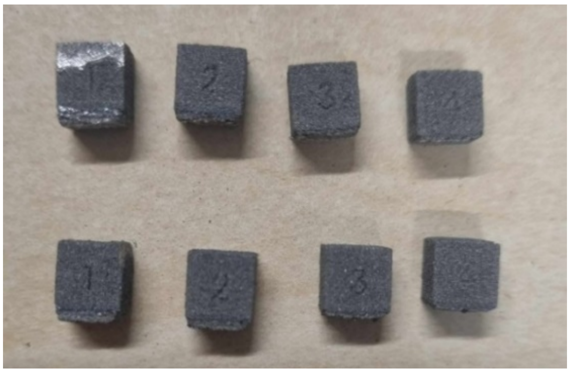

Fig. 2. 3D printed cubes using the SLM method

4. RESULTS AND DISCUSSION

To assess the quality of the printed zinc cubes, we measured their density using Pyramis Dentas software. This software helped us identify optimal printing parameters, including layer thickness, support structures, and internal filling patterns, along with consistent laser settings throughout the Selective Laser Melting (SLM) process.

During the printing process, we observed the presence of zinc vapor, as seen in Fig 3. The high vapor pressure of zinc during SLM can lead to several issues. Entrapment of Zn vapor within the melt pool can cause gas bubbles, compromising the density and overall quality of the printed parts. Additionally, the vapor can eject molten material and displace surrounding powder, further affecting quality. In the confined environment of the SLM chamber, a high concentration of vapor and ejected particles can hinder the laser beam through Rayleigh and/or Mie scattering. This scattering disrupts consistent processing and contributes to variations in the final printed product [12,13].

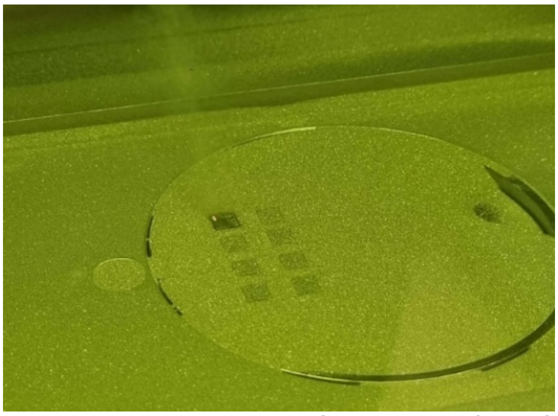

Fig. 3. Zinc Vapor Emission During SLM Printing of Zinc Cubes

The weight of the samples in air and after immersion in ethyl alcohol were measured using an electronic balance. The density of each sample was then calculated according to the Archimedean principle, factoring in the ethyl alcohol temperature (22°C). The measurement uncertainty for the weight was ± 0.0001 g. To enhance measurement precision, the density measurements were conducted four times for each sample [14,15].

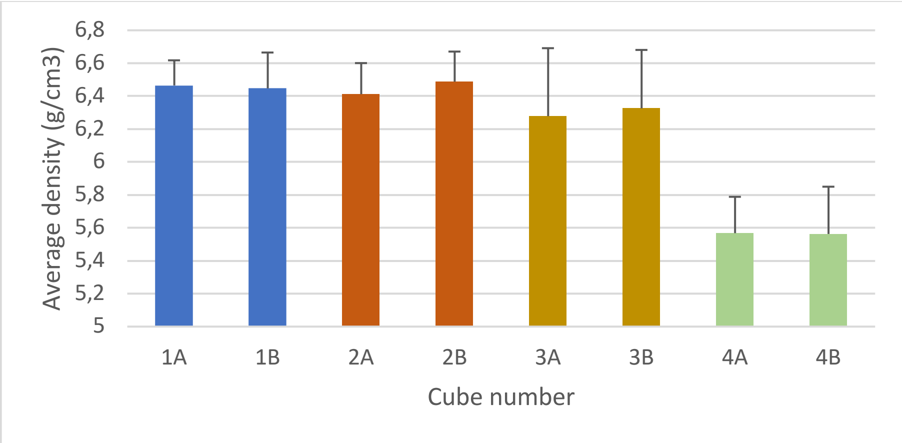

Fig. 4. Density Variations of 3D Printed Zinc Cubes Measured by Archimedean Principle

We measured the density using a device from Intertech Industrial and laboratory scales from Axis. Density variations were observed across the printed cubes (Fig. 4). Cube 2B exhibited the highest average density 6.48 g/cm³. Cubes 1A and 1B exhibited high density on average too 6.45 g/cm³, followed by cube 2A 6.41 g/cm³ and cubes 3A and 3B had average density 6.28 g/cm³ and 6.33 g/cm³), all showing good density. Conversely, cubes 4A and 4B had the lowest density, with an average of 5.57 g/cm³. Standard deviations for all cubes varied between 0.15 and 0.41 g/cm³. These variations can be attributed to porosity formation, a common challenge in SLM with zinc. Each cube was compared with its corresponding counterpart to ensure consistent evaluation across all samples.

5. CONCLUSION

In this study, we successfully fabricated zinc cubes using Selective Laser Melting by optimizing key process parameters, including laser energy, printing speed, density, and layer thickness. Despite these optimizations, variations in density were observed among the printed samples, likely due to the high vapor pressure of zinc, which can lead to gas entrapment, material ejection, and laser beam scattering.

Future research should focus on further optimizing the SLM process parameters to address these issues. This could involve experimenting with different layer thicknesses, support structures, and internal filling patterns, as well as adjusting the laser settings to minimize vapor formation and scattering effects. By systematically varying these parameters and analyzing their impact on density and quality, it may be possible to produce more consistent and reliably printed samples. Additionally, incorporating advanced monitoring techniques during the printing process could help in real-time detection and mitigation of defects, further improving the outcomes of SLM-fabricated zinc parts.

Acknowledgment

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THE USE OF DATA, ITS BENEFITS AND LIMITATIONS PERCEIVED BY INDUSTRIAL ENTERPRISES

Abstract

The aim of this paper is to present the results of a survey aimed at investigating the approaches of industrial enterprises to data collection and analysis. The survey also aimed to determine the extent of data use in business processes and to identify the limitations and benefits of data collection perceived by the representatives of the enterprises.

Key words: Data, Use of data, Industrial enterprises

1. INTRODUCTION

The amount of data is continuously growing, with the forecast to exceed 180 zettabytes of the volume of data generated, consumed, copied, and stored by 2025 [1]. Along with the volume of data, the importance of proper data management and data analysis to make informed decisions is increasing in the current digital era.
Data and its proper handling are the driving force behind the digital transformation of enterprises and their transition to a data-driven organization [2]. Data and analytics are also key enablers for the successful implementation of the Quality 4.0 concept [3]. The importance of data and its proper analysis has been also enshrined in the ISO9000 series of standards for years. Specifically, data are directly related to one of the quality management principles, evidence-based decision making. Among the potential key benefits that ISO9000 mentions for this principle are improved decision-making processes, the ability to achieve goals, or operational effectiveness [4].
In order to determine the extent to which data is used to make informed decisions in other activities and to find out what limitations companies operating in the Czech Republic face, as well as what benefits they perceive, research was conducted, the findings of which are presented below.

2. METHODOLOGY

A questionnaire survey was conducted to determine the current level of data use to inform decisions. The aim of the survey was to obtain information on the methods and tools used for data collection and analysis in companies, to identify the benefits and barriers perceived by companies and to determine the current level of use of data for informed decisions in business processes. The questionnaire was developed using

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an online tool Microsoft Forms and respondents were approached mainly electronically. The main reasons for electronic data collection were the possibility of quick response and minimal implementation costs. The target group of respondents was companies operating in the industrial sector. Descriptive statistics tools were used to analyse the collected data. Microsoft Excel software was used to create graphical outputs.

3. RESULTS AND DISCUSSION

During the questionnaire survey, responses were obtained from 110 respondents. The largest share - 60% of respondents represent large companies (with 250 or more employees), 29% of respondents come from medium-sized companies (50 to 249 employees) and 11% of respondents represent small companies with up to 49 employees.
More than 50% of the respondents were representatives of companies based in the Moravian-Silesian region. The most represented sectors were the automotive industry, which accounted for 56% of respondents, engineering, which represented 15% of respondents, and metallurgy, which accounted for 7% of the respondents.
To determine to what extent data is used to inform business processes decisions, respondents answered the following question. What percentage of the data that the enterprise obtains and has available is used in the enterprise to inform decisions in other activities. For this question, 108 valid responses were obtained, as 2 respondents expressed an inability to make this estimate.
The survey showed that small firms use the most data (62%) on average, followed closely by large firms, which use 60% on average. Medium-sized firms use 58% of their data on average. The overall average percentage of data used to inform decisions without distinction of firm size is 59%.
Based on the percentage of respondents, the responses were sorted into 5 categories based on the level of data usage. The very low level corresponds to firms using no more than 25% of the data available to them, the low level includes firms using 26-50% of their data, and the medium level indicates firms using 51-75% of their data. However, the most represented group was the high level, which represented the use of 76-99% of the data, with 31% of the respondents falling into this category. A special group then consists of firms that use 100% of the data they obtain and have available, and the data use rate of these firms was termed as complete. The representation of all categories depending on the size of the enterprise are shown in the Tab. 1.

Tab. 1. Data usage rate based on the size of the company

Rate	**Company size**			**Total**	**Total [%]**
	Small	Medium	Large		
Very low	1	5	9	15	14%
Low	3	6	17	26	24%
Medium	3	11	13	27	25%
High	4	10	20	34	31%
Complete	1	0	5	6	6%
Total	**12**	**32**	**64**	**108**	**100**

The purpose of the survey was also to identify the limitations of data collection and further use perceived by the respondents. More than half of the respondents consider that the biggest limitation is the lack of people who would be able to implement appropriate tools for effective data collection and data analysis. 71% of the respondents of large companies and 69% of medium companies reported the lack of people able to implement data tools. In the case of medium and large companies, the other limits mentioned are much less represented. For large firms, the second limitation most frequently mentioned is the lack of appropriate data tools, identified by 38% of large firms, and slightly less frequently mentioned was the lack of funds to purchase data tools. For medium-sized firms, the second most frequently mentioned limit was the lack of funds to purchase data tools, mentioned by 44% of medium-sized firms. The lack of appropriate data tools was then mentioned by just under one-fifth of medium-sized firms, making it the third most frequent limit for medium-sized firms. In contrast to medium and large firms, small firms most frequently mentioned the lack of funds to purchase data tools, which was considered a limit by 58% of small firms. Half of the small firms also mentioned the lack of people able to implement data tools as a limit. The overall picture is shown in Fig. 1.

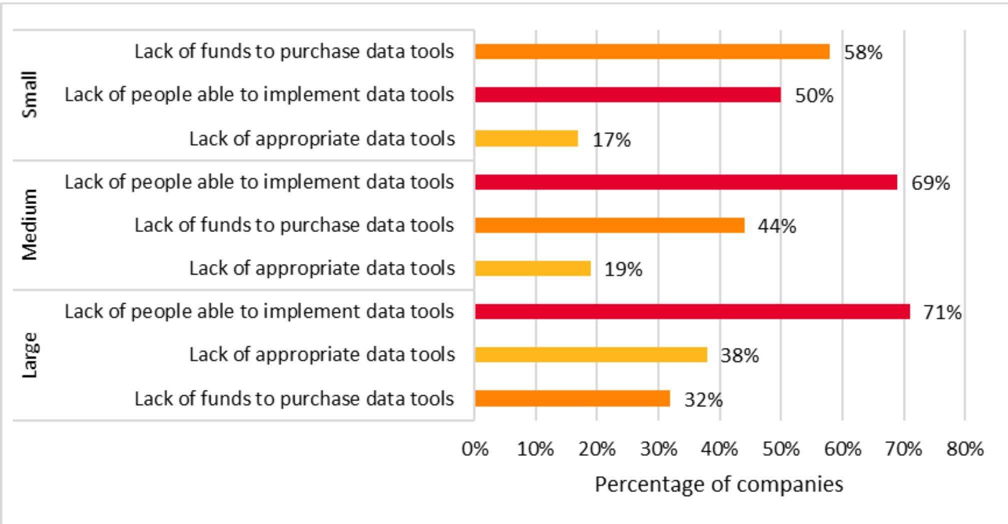

Fig. 1. The most common limitations based on the size of the company

In addition to limitations, respondents also reported the benefits of data collection and analysis that are perceived in their enterprises. For medium and large companies, the most frequently mentioned benefits were the same: streamlining processes, optimisation of production processes and prevention of non-conformities. The prevention of non-conformities was the third most frequently mentioned benefit for medium and large companies. The most frequently stated benefit for medium-sized companies was streamlining processes, which was identified as a benefit by 88% of medium-sized companies. On the other hand, for large firms, the most common benefit was the optimisation of production processes, which was mentioned by 77% of large firms. For small companies, streamlining processes and prevention of non-conformities were also among the three most frequently stated benefits of data collection and analysis, but the most frequent benefit differs - it is reducing waste, identified by 67% of small company representatives. The general overview, including the percentage of companies that reported the advantage of data collection and analysis, is shown in Fig. 2.

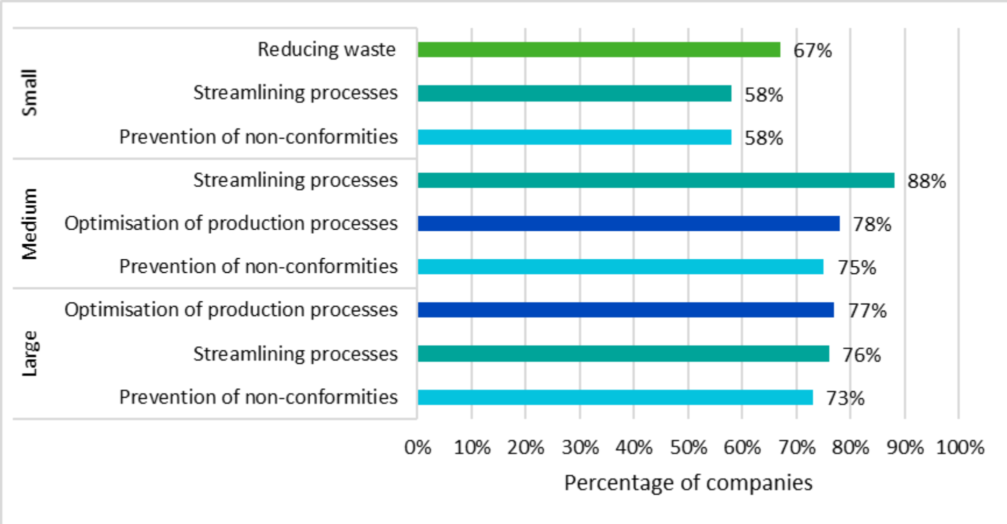

Fig. 2. The most common benefits based on the size of the company

Among the limitations of the survey is that the percentage of data that the company uses in its business processes, as well as limitations and benefits perceived by companies, was only assessed based on the statements of the respondents and can therefore be subjective. For a more objective assessment, it would be advisable to conduct in-depth qualitative interviews with company representatives or to assess the level of data use through specific indicators. However, during the questionnaire survey, contacts were made with representatives of enterprises who will be approached further to conduct more detailed qualitative research in the future.

4. CONCLUSION

The effective implementation of all tools and methods associated with modern quality management, as well as with Industry 4.0 and technological trends, requires proper data collection and analysis. The survey carried out showed that 63% of Czech companies show only a low or medium rate of data used in their business processes. As a result, these companies are wasting and not using a substantial part of the data at their disposal and may be missing essential information that could help them fulfil the principle of evidence-based decision making and the objective direction of the company.
Based on the most frequently mentioned limitations by the respondents in the survey, it can be concluded that while large and medium-sized companies see the lack of people able to implement data tools as the most common limitation, small companies are more often faced with the lack of financial resources to purchase appropriate data tools.

The most frequently mentioned benefits of data collection and use in medium and large companies are streamlining processes, optimisation of production processes and prevention of non-conformities. But for small companies the most frequently mentioned benefit is reducing waste. The conclusion shows that the perception of benefits and limits to data use is different for small firms compared to medium and large enterprises. Differences and specific conditions and requirements of enterprises should be taken into account when implementing data analysis tools.

Acknowledgment

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THE IMPACT OF WORKING FROM HOME ON TIME MANAGEMENT AND EMPLOYEE PRODUCTIVITY

Abstract

The aim of the publication is an analysis of the current state of productivity and the utilization of time management principles by employees in an industrial enterprise, during work from office and work from home. The first part explains the concepts of time management and work from home, along with other terms related to the topic. The second part consists of the methodology of the work, including research utilizing a comparison of workday snapshots. The third part introduces proposals for measures to improve the utilization of time management principles during work to increase employee productivity.

Key words: Work from home, Time management, Productivity, Workday Snapshot

1. INTRODUCTION

Today, as the world gradually recovers from the COVID-19 pandemic, teleworking is becoming an important aspect of working life. This phenomenon, also known as 'working from home', has proven its relevance not only as a crisis measure but also as a permanent component of modern work strategies.

Working from home offers many benefits, but also challenges. People's ability to work from home is strongly linked to their profession and the tasks they have to perform. People often find it difficult to meet the demands of work and personal life. Work flexibility is one way of providing greater opportunities to meet and effectively integrate the increasing demands of both work and personal life.

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1.1. Principles and methods of time management

Time management is a set of tools that enable the effective use of time to achieve job-relevant goals [1]. Time management is significantly related to increasing performance and reducing stress, as it enables employees to work smarter and avoid heavy and inefficient work. Time management also takes into account free time and space for relaxation which helps to maintain physical and mental health [2]. There are a wide variety of time management methods and techniques, the most well-known are as follows:

- Eisenhower Matrix – The model is related to the key concepts in task evaluation, which are the terms "important" and "urgent". The term "important" is associated with anything good for professional or personal development in the long run. The term 'urgent' describes anything that someone is expected to complete. From the definitions, it is clear that it is possible to restructure tasks so that they do not become urgent [3]. The first quadrant ("get it done") – includes all important and urgent tasks that should be completed personally and cannot be postponed. The second quadrant ("schedule it") – includes important but not urgent activities, i.e. these tasks can be completed at the correct, pre-selected time. Tasks from the second quadrant should always be scheduled. The third quadrant ("decline it") – includes urgent but not important tasks, i.e. tasks can be abandoned and delegated to another. The fourth quadrant ("resist it") – includes tasks that are neither important nor urgent and can be crossed off the list.
- Getting Things Done – is a widely accepted approach to task management, based on the core principle that the greater the volume of information occupying your thoughts, the more difficult it is to discern what to focus on. As a result, you end up spending more time thinking about tasks than doing them [4]. It consists of 5 steps: capture, clarify, organize, reflect, engage.
- ALPEN technique – is very helpful for completing short-term daily tasks. The acronym comes from the English words A – Activity, L – Long, P – Priority, E – Extra Time, N – Note [3].
- Pareto Principle – This principle refers to the idea that by completing 20% of the work, it is possible to achieve 80% of the results of all the work. The idea is that in time management, employees should focus on the 20% of the work that is most important, as this 20% accounts for 80% of the results. By using Pareto diagrams, the problems of identifying the important work can be identified and contribute to achieving greater efficiency, reduction and saving of resources [3].

1.2. Types of work by place where they are performed

The terminology regarding telework is not always precise, as the definitions of the terms vary in different studies dealing with this issue. We recognize:

- Teleworking can be defined as any form of substitution of information technology for work-related travel; it is the transfer of work to workers instead of the transfer of workers to work [5]. Telecommuting means performing professional activities outside the traditional office environment, whether online or not [2].

- According to the Cambridge Dictionary, work-from-home is a situation in which an employee works predominantly from home and communicates with the company by email and telephone. It is a type of employment in which the employee works part or all of his or her regular working hours at his or her primary residence. This reduces their commuting time and potentially gives them access to more flexible working hours [6].
- The hybrid model is a configuration where workers spend two to three days a week in the office and two to three days working from home. It can be implemented in workplaces where some work can be done efficiently from home, but there is still a need for collaboration [6]. It is intuitively appealing and balances the benefits of working in an office - the ability to collaborate, innovate and interact with colleagues face-to-face - with the flexibility, silence and elimination of commuting that come with working from home [7].

1.3. Time studies and work standardisation

Efficiency and productivity depend strongly on the consistent use of working time. Although there are different views, standardisation of working time remains an effective means of managing working time properly. The appropriate implementation of labour standardisation is based on the adequate use of time studies, which represent the basis for the establishment, updating and control of working time consumption standards and focus in particular on the time distribution of work activities, the duration of individual work tasks, the consumption of working time and the causes of time losses. In particular, the following are used: workday snapshots, snapshots of work operations, and snapshot observation [8].

2. METHODOLOGY

The aim of the research is to propose, on the basis of the working day of a selected group of employees (lower management) and through calculations for work norming, measures to optimize the utilization of time management principles when working from home in order to increase the productivity of employees and improve their time management.
The baseline survey was conducted by:

- Methods of structured interviews, focused on homeworking - the questions were aimed at finding out the current situation in the organisation in relation to working from home, the staff structure and the overall functioning of the organisation,
- Workday snapshots that have been analysed and evaluated based on the principles of work standardisation - the aim of the snapshot is to obtain an accurate balance of the real use of working time, i.e. to identify the different types of working time and determine their duration. The information obtained is important for the identification of time losses. Defining the extent and causes of these losses subsequently allows to develop measures to eliminate or reduce them [8]. Work activities during office work and while working from home were recorded.

The research was conducted in an industrial enterprise that operates in the automotive sector, it is classified as a large enterprise based on the number of employees.

3. RESULTS

Through a structured interview, details of the organizational structure of the enterprise and the classification of individual employees into specific categories were collected. Based on the knowledge base, a group of employees was identified whose work activities are related to administrative activities and are not directly linked to production. The request to complete the snapshot was shared with 40 employees. The completed snapshots were analysed based on work norming principles deduced from ergonomics.

Tab. 1. Results of calculations focusing on office work (own processing, 2024)

Employee	Worker's employment level (%)	Proportion of unnecessary time consumption caused by the employee (%)	Total percentage of opportunities to increase productivity of work (%)
1	94.17	4.85	5.10
2	96.07	3.92	4.08
3	82.40	3.70	20.69
4	100.00	0.00	0.00
5	95.34	4.66	5.41
6	88.67	6.62	8.37

Tab. 2. Results of work-from-home calculations (own processing, 2024)

Employee	Worker's employment level (%)	Proportion of unnecessary time consumption caused by the employee (%)	Total percentage of opportunities to increase productivity of work (%)
1	87.27	12.72	14.58
2	98.24	1.75	1.78
3	82.05	10.25	24.32
4	89.79	10.20	11.36
5	86.25	10.75	7.35
6	85.34	11.66	12.34

3.1. Observation

It can be observed that the level of employment of a worker does not differ significantly during office work (Tab. 1) and work from home (Tab. 2), while only a marginal decrease was observed during work from home. However, the proportion of wasted time was significantly higher during work from home than during office work. This can be argued to have been offset by the longer amount of time actually worked during homeworking. The overall percentage of opportunities to increase labour productivity is precisely during homeworking. The extent of time actually worked (T) was more extensive during

working from home than during working from the office, which may be due to more frequent breaks. The actual measured time of normative work, however, was longer during work from the office, which means that employees spend longer in the office performing activities that fall within the job description.
Based on the results of the structured interviews and the analysis of working day snapshots, where work activities performed in the office and while working from home were examined, we came to the following conclusions:

- **Advantages of working from home and working from the office**
  Employees consider that the biggest advantage of working from home is the time saved by travelling (85%), the second biggest advantage is the possibility of better work concentration (62.5%) and the third is the flexibility in working hours (52.5%). Other benefits indicated are saving on transport costs, reducing emissions, being able to stay at home in case of children's illness, avoiding open office and air conditioning, work-life balance, and privacy. The biggest advantage of working from the office was the collegiality and the possibility of personal interaction (88.8%), the availability of work tools and technical equipment (25%) as well as the separation of work and private life (21.3%). Other benefits cited were relationship building, faster circulation of information, evidence of employee's diligence by supervisor, fewer distractions, and faster problem solving. However, it was also mentioned that working from the office does not bring any benefits.
- **Disadvantages of working from home and working from the office**
  Based on the respondents' answers, the factors that are most disruptive to working from home include inadequate technical equipment (23.8%), inadequate ergonomic equipment (21.3%), and lack of discipline (21.3%). Another proportion of respondents (16.6%) said that nothing disrupts their work from home. Among the negative aspects, the presence of household members, being overwhelmed by online meetings, limited access to information and unstable internet were mentioned. The most distracting factors for working from the office were identified as disruptive office environment and noise (81.3%), excessive face-to-face meetings (45.0%), and having to wear formal clothes (13.8%). Other factors include lack of creativity due to distracting environment, expectation of immediate problem solving due to physical presence and assignment of tasks beyond job duties, open office, difficulty concentrating, as well as lengthy transfers to conference rooms.

4. CONCLUSIONS

The research results suggest that the actual measured time of normative work is higher when working from the office, but the amount of time actually worked is longer when working from home than when working from the office, probably due to more frequent breaks. These breaks have been shown to account for a proportion of unnecessary time consumption, but may also serve as a means of increasing productivity.
It can be concluded that there are differences in the productivity of work depending on the specific place where it is performed, but the individual advantages or disadvantages are compensated for in different ways. Alternative places of work are not a panacea for obtaining a work-life balance. Each location brings different benefits but also challenges. In terms of employees' assessment of time management, their comments indicate that

they actively make use of the time management methods available, but would welcome improvements in the opportunities provided by the company. Employees prefer to work from home, as they feel more productive when they do so. Productivity is likely to remain the same or improve with extended home working. It is important to stress the need for further research on teleworking, its impact on people, firms and cities, and whether regulatory frameworks will be able to address the issues raised, as it is a relatively new and unexplored concept. These researches need to take into account the time demands and complex factors affecting the performance of work.

4.1. Limitations

The survey results may be biased because respondents may have expected the results to influence future management decisions on flexibility. There is a likelihood that responding positively to questions about working from home will increase the likelihood that flexibility will be maintained.

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THE EVOLUTION OF INTEREST IN THE FIELD OF INDUSTRIAL ENGINEERING IN SCIENCE AND EDUCATION

Abstract

Industrial engineering integrates knowledge from several engineering disciplines and is constantly developing. Given the importance of industrial engineering for the successful operation of industrial enterprises, the article focuses on developments in this progressive field of science based on published contributions in indexed databases. The article also analyses the evolution of the number of industrial engineering and management graduates at Slovak universities.

Key words: Education, Industrial engineering, Industrial management

1. INTRODUCTION AND LITERATURE REVIEW

Industrial engineering originated in the United States at the beginning of the 20th century. The basic element is modern industrial production, the object of research is large-scale production and the socio-economic system. Industrial engineering is an interdisciplinary engineering discipline that is gradually built and developed on the basis of production engineering, management science and systems engineering. It also optimizes the allocation of production system elements such as people, equipment, materials, information and environment with the synergy of systematic planning, design, evaluation and innovation of industrial production processes so as to improve industrial productivity and highlight social and economic benefits [1]. In the field of industrial engineering and industrial management, the key elements for achieving long-term competitiveness at the national and international level, increasing the attractiveness of the region's business and overall employability, which include flexibility, adaptability,

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resilience and competence [2]. Industrial engineers themselves work interdisciplinary during their work, and also within the study of industrial engineering there are development challenges that must reflect the current situation in the field of digitization and automation [3]. Industrial engineering emerged as an interdisciplinary field by combining engineering and administrative management. It has become the basis of competitiveness and continuous improvement, and this has caused jobs in industrial engineering to grow faster than any other engineering branch in recent years [4]. Demand for industrial engineers is high and expected to continue to grow. Employment of industrial engineers is projected to grow 10% percent from 2019 to 2029, faster than the average for all occupations [5]. Another statistic predicts that demand for industrial engineers will grow by 12% between 2022 and 2032 [6]. However, it is also important to promote this industry among young people who have the potential for employment in industrial engineering and to capture talents who can contribute to the development of this industry and increase their interest in studying at technical universities. The ability to reflect the needs of practice is important for the sustainable long-term perspective of universities. And not only in the form of providing fields of study that are in demand in terms of the provision of the functioning of the economy. An important factor is the ability to provide students with the opportunity to acquire the competences required for industrial engineers today but also to be prepared for new challenges. From this point of view, research in the field of industrial engineering is important, as well as monitoring the trends of its further development. For the professional community, the sharing of knowledge is of fundamental importance, whether in the form of publishing scientific articles, organizing conferences, professional forums or workshops, where a space is created for sharing knowledge. The aim of the article is therefore to compare how interest in industrial engineering is developing in science and education.

2. METHODS AND METHODOLOGY

To meet the objective of the paper, we have focused our analyses on the area of research and education. For the research area, we have chosen to analyze published papers in the field of industrial engineering. For the purposes of the article, the authors performed an analysis focused on the occurrence of the field of Industrial Engineering within the publications registered in the world scientific databases Scopus and Web of Science (WoS).

We focused the subsequent analysis on the area of education. We searched for information about taught study programs on the official websites of Slovak universities. Studies in the field of industrial engineering are made possible by three public universities, in all three cases they are universities. Neither state nor private universities offer industrial engineering studies. We drew data on graduates in the field of industrial engineering from the statistical yearbooks of education. In the education yearbook published for each relevant year, data on graduates by field of study, study programs, form of study and level of study are listed [7].

3. RESULTS AND DISCUSSION

Scientific articles recorded in the world scientific databases Scopus and Web of Science (WoS) focused on published research results in the field of industrial engineering were analyzed. For both databases, a filter was used to search for the keyword (Topic):

Industrial Engineering. We found a total of 208,547 results found in the Scopus Database and 67,604 results found in the WoS database. Subsequently, the authors created a graph that shows the period from 2014 to 2024. The result of the analysis can be seen in Fig. 1.

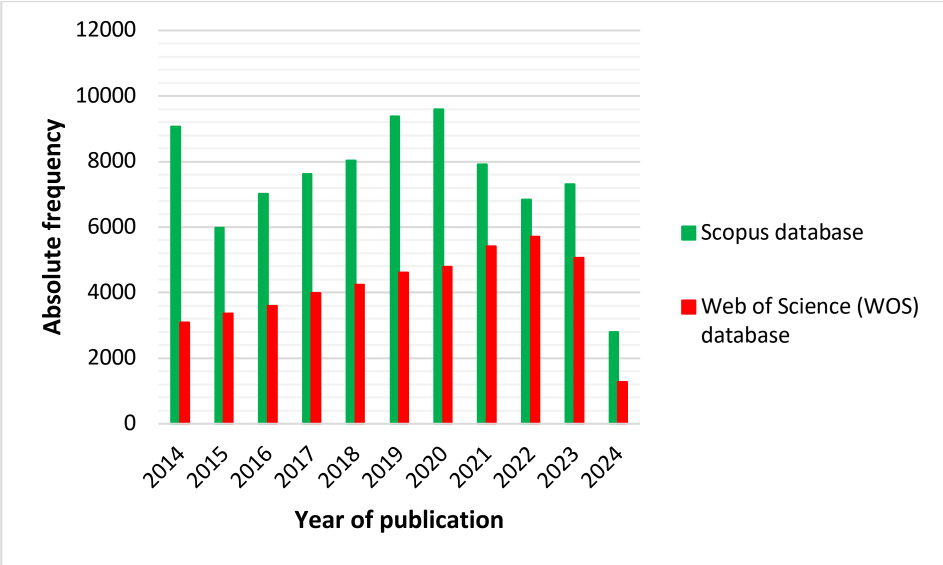

Fig. 1. Occurrence of industrial engineering topic in publications (own elaboration, 2024)

Fig. 1 shows the occurrence results in two world scientific databases. It is clear from the results that the number of publications recorded in the WoS database is constantly increasing, while the number of publications recorded in the Scopus database increased until 2020, and from that year there was a decrease in the number of publications recorded in the analyzed database.

Subsequently, the authors of the article proceeded to the analysis of universities that provide education in the field of industrial engineering in Slovakia. For the needs of the analysis, publicly available information was used on the websites of universities as well as from CVTI of the Slovak Republic. The results of the analysis focused on education providers in the territory of the Slovak Republic can be seen in Tab. 1.

Tab. 1. The overview of universities offering industrial engineering studies in Slovakia (own elaboration, 2024)

University	Faculty	Field of study	Number of study degrees
Technical University of Košice	Faculty of Manufacturing Technologies in Prešov	Industrial Management	3
Technical University of Košice	Faculty of Mechanical Engineering	Industrial Engineering	3
University of Žilina	Faculty of Mechanical Engineering	Industrial Engineering	3
Slovak University of Technology in Bratislava	Faculty of Materials Science and Technology in Trnava	Industrial Management	3

Tab. 1 shows that all three universities at 4 faculties provide education in the field of industrial engineering. This study is concurrently offered at all three degrees of study (bachelor's, engineering and doctoral). Furthermore, the authors analyzed the statistical yearbooks of higher education institutions for the last ten years, the results of which can be seen in Fig. 2.

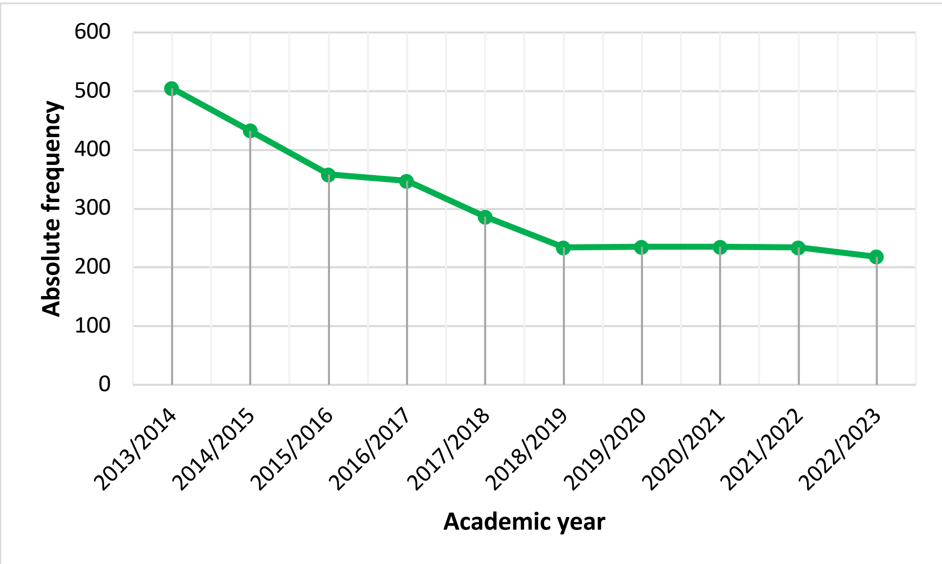

Fig. 2. The evolution of the number of industrial engineering graduates (own elaboration, 2024)

The analysis was carried out for study fields in group 2645, which combine study fields in the Industrial Engineering group. The annual yearbooks contain absolute numbers in the sum for all four faculties (Fig. 2) for I. and II. degree of study. Fig. 2 expresses the fact that over the last 10 years, the number of graduates in Slovakia has decreased by more than ½. Another negative finding is that the number of graduates has decreased over the last period, despite the increase in secondary school graduates. From the mentioned trend of drop in graduates, it is clear that there is insufficient awareness among high school students about the attractiveness of studying industrial engineering. Choosing a future profession, in addition to the necessary information, there are also other aspects related to planning a future career.

During career planning, it is necessary for a person to know himself and realize his strengths and weaknesses. He decides which profession is best for a person based on the assessment of his abilities and the subject of interest. The choice of a profession is influenced by factors such as the benefits of work, the person's interest, abilities and advantages and disadvantages combined with private life and family. Another important decision that needs to be made after choosing a profession is choosing the industry in which the person will work [8]. Choosing a branch can be difficult unless a person has a clear affiliation to a specific profession. Industrial engineering is a versatile and key branch of engineering that affects other industries, from manufacturing, technology, retail to healthcare. Therefore, the presence of experienced industrial engineers is a common denominator in various sectors, industrial engineers are crucial in increasing efficiency and quality in all sectors [9, 10].

4. CONCLUSION

From the results of the analysis of the scientific databases Scopus and WoS, it is clear that researchers are constantly working on the issue of Industrial Engineering and the number of publications in the given field is increasing. The above-mentioned fact demonstrates the topicality of the use of industrial engineering methods as well as the solution of research problems in the analyzed area. Another interesting but at the same time negative finding is that the number of Industrial Engineering graduates in Slovakia has dropped from 505 to 218 over the last 10 years. Based on the above, there is a need to focus on systematic outreach and improved marketing so that enrolment numbers as well as graduate numbers start to rise again.

Among the limits of the research we can include the fact that the analysis of scientific databases did not follow the research areas, but only the number of publications. Another limitation is that the analysis of study fields was carried out only on the territory of the Slovak Republic. In future research, the authors of the article plan to focus on the professional requirements of practice for the competences of industrial engineers, as well as on the comparison of study plans for the study of industrial engineering and management and the analysis of the structure of the taught subjects.

Acknowledgment

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THE POSSIBILITIES AND USAGE OF INTERACTIVE TECHNOLOGY IN THE LABORATORY

Abstract

The main benefits of an interactive whiteboard are improving student engagement and teacher-student interaction. The goal contribution was to propose the possibilities of using interactive technology in the laboratory and to create a creative and interesting environment for students. A great tool is the display of a 3D visualization of the finished project when it is possible to present the production hall to the students at the lecture, simultaneously move between them, and offer them control in the 3D visualization with a tablet. The various programs with the connected whiteboard are used more for presentation and partial editing of a production layout. The student can move around the production hall by dragging the pen on the tablet screen. One of the benefits is facilitating and streamlining the learning process and developing students' creativity. Interactive hardware (interactive whiteboard) and software (multimedia systems) were used to solve the work. The conclusion consists of an evaluation of the benefits of using the interactive whiteboard in the laboratory. The mentioned applications can be used in most subjects; the advantage is that the changes made by the teacher on the interactive whiteboard are simultaneously updated in the document available to the students.

Key words: Education, Industrial engineering, Industrial management.

1. INTRODUCTION AND LITERATURE REVIEW

Interactive whiteboards are a modern and popular technological tool used in the field of education and presentations. Their use brings many opportunities to improve teaching and student engagement. Currently, trends in the field of education focus on the integration of interactive content into the learning process. Interactive whiteboards

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help to activate students with the help of engaging topic content, enhance long-term memorization of the given situation (solved problem) and connection with the result of this activity (task), and improve students' interest in the interpretation of the subject matter during the teaching process. By using an interactive whiteboard, it is possible to achieve mutual active communication between the user and the computer. This type of touch-sensitive surface enables the display of content with maximum clarity. Interactivity requires a new approach, which is reflected in the use of software applications.

2. METHODS AND METHODOLOGY

A visual standard was created for working with an interactive whiteboard and its accessories in the Laboratory of Designing Production Systems and Processes at the Department of Industrial Engineering, Faculty of Mechanical Engineering at the University of Zilina. This visual standard is placed on the table where educators can view it and follow it if they want to use the interactive whiteboard. By analyzing the possibilities at the university, it was found that the mentioned interactive technology has several possibilities of use. One of the possibilities mentioned is working with different programs that are compatible with the board or the ActivInspire program. These are mainly programs such as Microsoft PowerPoint, where we can project a presentation on the board and use the ActivInspire program to highlight or write notes that would help to better understand the issue of a specific subject in class. The Microsoft Word program is similar, when it is possible to move and show the text on the board and then clarify the issue of the given topic using the ActivInspire tools. We can also display photos or play any video on the board either on the Internet or directly from the computer. The Vistable program is also no exception, all that is needed to work with this program is the complete connectivity of a whiteboard, desktop computer or laptop, data projector, and a tablet can also be used together with a pen. Subsequently, it is possible to move and add modifications (machines, workplaces, buildings, cars) in the program. The program with the connected whiteboard is therefore used more for presentation and partial editing and not for creating a production layout. A great tool is the display of a 3D visualization of the finished project, when it is possible to present the production hall to the students at the lecture and at the same time move between them and offer them control in the 3D visualization with a tablet. The student can move around the production hall by simply dragging the pen on the tablet screen. Fig. 1 shows the work in Vistable in a 2D and 3D view of the production hall. This assignment is processed in the subject Designing production and assembly systems in the 3rd year of bachelor's studies.

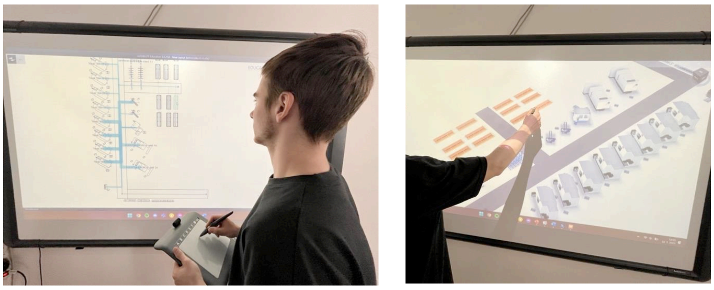

Fig. 1. View 2D and 3D - working with Vistable software on an interactive whiteboard (own elaboration, 2024)

3. RESULTS AND DISCUSSION

A great use of a large interactive whiteboard is testing, for example using the kahoot application for such testing we will also need an Internet connection. The teacher prepares the test before the lesson begins. When the teacher comes to the class, he turns on the blackboard and sets the test on the blackboard, after starting the test, students write the code that is displayed on the screen of the kahoot environment into their mobile phones, tablets, laptops or desktop computers. In addition, Kahoot also offers a "Ghost Mode" feature that allows users to play games against their own past performance or against the performance of other users. This feature provides the ability to track and improve your progress and compare yourself to others.
Studies conducted by university researchers have found Prezi to be a more engaging and effective form of presentation than PowerPoint. The principle of creating a presentation through a white canvas, gradually revealing information and using the presentation path guarantees that the presentations will be memorable, original and dynamic. The platform is used to bring the presentation to life using movement, zoom and spatial tools. An open canvas that is unique will allow you to view and organize the presentation as a whole into topics. Prezi includes advanced features for inserting images, text, icons, shapes, graphs, video and animations, the presentation can be shared with students.
The term such as concept maps, mind graphs or mind maps have been known for a long time. The principles of creating mind maps can be learned and transferred to the digital space. Clear, creative and original thinking can help students learn, revise and take notes. [1]
EdrawMind software is a tool for creating mind maps, diagrams and other visual tools for organizing and presenting information. This software allows you to create and edit different types of diagrams, including mind maps, organizational charts, Gantt charts, process flow diagrams and many more.
EdrawMind also offers various features for sharing and collaborating with other users, such as the ability to share and comment on diagrams in real time, import and export to different formats, and more. EdrawMind is used for a variety of purposes, including project planning, brainstorming, creating presentations, and more. The program is free, eliminating the need to invest in software. But it is necessary to download the software. [2] With the onset of the digital era, new possibilities for the university environment also appear. One of these solutions is the Office 365 platform, which provides

comprehensive tools for effective university management, communication and online learning. If a student or teacher wants to learn or improve in using an e-mail client, organizing work time, recording and backing up documents, sharing materials, creating tests, preparing presentations and conducting online classes, this education is intended for him. The Office 365 platform enables educators and students to access modern productivity tools from Microsoft. [3]

Office 365 is applications and services that exist on mobile, computer and web browser. Office 365 for schools includes: office online (word, excel, powerpoint), document sharing (sharepoint), shared calendar, professional email (outlook), personal data storage (onedrive), online education (teams, classnotebook). These applications can be used in most subjects; the advantage is that the changes made by the teacher on the interactive whiteboard are simultaneously updated in the document available to the students. The University of Zilina provides this package to students completely free of charge.

The Buncee interactive tool shows the real experience of the lesson, presented in the form of multimedia posters, interactive worksheets and online quizzes. With this application, the subject matter can be explained in a new and engaging way. Online login and diverse material libraries provide inspiration and simplify the use of individual applications.

Wizer.me is an online platform for creating interactive learning materials such as tests, quizzes, challenges and other activities. It serves educators and educational workers as a tool for creating personalized and dynamic educational materials that can be adapted to the individual needs of students and thus improve their educational experience.

Files in the ActivInspire program are created in the form of demonstration notebooks (flipcharts) with an unlimited number of pages, which can contain various elements such as texts, animations, videos, audio samples, hyperlinks, embedded Internet browser, active elements from the resource library or created according to your own ideas , notes, annotations on the desktop and assignments or tests. Actions and restrictions can be assigned to each object. By using drawing tools, geometric shapes, images and sounds, you can create a basis for creating interactive tasks, such as secretarial, completing words or creating pairs.

Creating videos for educators is an important part of teaching, but many are often afraid of the complex preparation. However, with Video Editor, this is no longer a problem. With this tool, he can quickly and easily create videos for his students and share them instantly.

4. CONCLUSION

The use of an interactive whiteboard in the field of education represents a modern and innovative approach to teaching. Based on the analysis of the use of the interactive whiteboard, we came to the conclusion that this technology can have significant benefits for teaching and learning. One of the main benefits of an interactive whiteboard is improving student engagement and teacher-student interaction. An interactive whiteboard allows information to be presented and shared in a dynamic and interactive way, which can lead to better understanding and retention of the subject matter.

Acknowledgment

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DIGITIZATION OF VALUE STREAM MAPPING VIA REAL TIME LOCATING SYSTEM

Abstract

This paper explores the use of Lean methods in logistics supported by the Internet of Things (IoT) and Real-Time Location Systems (RTLS). Lean methods, which have traditionally been used to increase efficiency and reduce waste, focus on improving the flow of materials, time, and information in logistics. This paper focuses on the integration of IoT and RTLS with a Lean approach to achieve greater automation, tracking and optimization of logistics processes through value stream mapping.

Key words: Value stream mapping, RTLS, Lean, improvement

1. INTRODUCTION

In recent years, the concept of Industry 4.0 has received considerable attention due to its potential to bring about a fundamental change in manufacturing strategies. [1]
The Industry 4.0 vision introduces and integrates advanced information and communication technologies (ICT) in the manufacturing environment in order to transform conventional manufacturing systems into autonomous and highly dynamic production systems with significantly improved performance. [2]
The Internet of Things (IoT) has been defined as a key technology and one of the main enablers of the Industry 4.0 concept. Thus, IoT is a technological concept that uses various sensors, micro controllers, and other integrated or dedicated end devices. Through these devices, real-time data can be collected from production machinery and equipment and logistics technology. This data can be shared between production resources, which include production equipment and people. This ability to share data with each other enables the transformation of a manufacturing system into a smarter more agile one. [3]

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2. VALUE STREAM MAPPING AND REAL TIME LOCATION SYSTEM

Value Stream Mapping (VSM) is a lean manufacturing tool that uses a flow chart to describe each step in the process. VSM is considered by many experts to be an essential tool for identifying waste, reducing process cycle time, and implementing process improvements. [4]
Although a flowchart can be drawn digitally, using digital drawing tools, this conventional method of drawing and manual data collection is often time consuming, inaccurate and unreliable. Researchers such as Ramadan et al. have identified the need to digitize the VSM process and have developed concepts such as dynamic value stream mapping, using RFID-based RTLS in order to identify the location of tags and create a set of rules for automated VSM map generation. [5]
The combined use of RTLS and VSM makes the data collection process more efficient and cost-effective. One of the main benefits is data accuracy. The data collected from RTLS is much more accurate and reliable than data that is collected by conventional methods such as stopwatches, operator tracking, etc. Also, the availability of "real-time" data allows the user to create a VSM with a dynamic nature due to the fact that it can be created at any point in time. [6]

3. RELATIONSHIP BETWEEN RTLS OUTPUTS AND INPUTS TO VALUE STREAM MAPPING

The following figure (Fig. 1) describes the relationship between outputs from RTLS and inputs to the VSM. The data from the RTLS system must be converted in order to process it in terms of creating rules for the automatic generation of the dynamic VSM map.

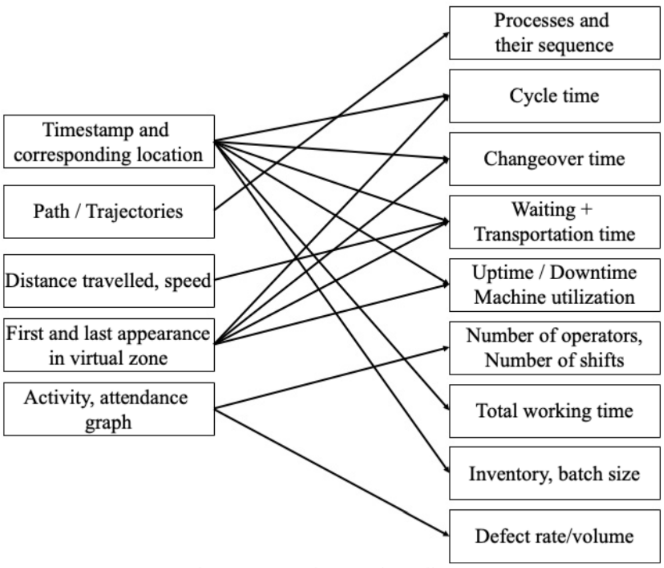

Fig. 1. Information flow
Source: Sullivan, B., P. (2022)

Based on the conversion of RTLS outputs to VSM inputs, a VSM map can be generated. The cooperation of VSM and RTLS in terms of intelligent manufacturing systems and internal logistics process control can bring several benefits to companies.

3.1 Advantages of RTLS integration into Value Stream Mapping

The advantages of RTLS integration into VSM are following:

- Accurate tracking and locating of inventory-RTLS enables accurate real-time location of materials, products or inventory. Combining RTLS with VSM allows a company to visualize the movement of these items throughout the logistics process.
- Streamlining material flow-using data from the RTLS system allows the business to identify potential wastage or non-value adding activities. This information enables the improvement and streamlining of material flow and minimization of inventory levels in warehouses where funds are tied up.
- Identification of bottlenecks in the logistics chain-identification of bottlenecks is key in the context of their elimination and overall improvement of the process in question.
- Improvement of process planning.

3.2 Disadvantages of RTLS integration into Value Stream Mapping

On the other hand, there are also disadvantages and each company must weigh the pros and cons well. Building an RTLS structure can be both costly and time consuming. Also, integrating RTLS with existing IT and manufacturing systems can be complicated and time-consuming. All these factors need to be weighed against business process improvement goals.

4. CONCLUSION

In the conclusion of this article, it is clear that the combination of Value Stream Mapping (VSM) and Real-Time Location System (RTLS) in logistics represents an innovative approach to process improvement and material flow management. The introduction of digital technology, specifically RTLS using RFID, brings many advantages over traditional data collection methods. The digital transformation of the VSM process enables the creation of more dynamic and accurate workflow maps. RTLS contributes to accurate real-time tracking and locating of inventory, enabling the organization to effectively visualize and optimize material and product movement. Streamlining material flow, identifying bottlenecks and improving process planning are other significant benefits of combining these technologies. The biggest benefit, however, is the accuracy of the data. RTLS data is more accurate and reliable than that obtained through traditional methods. This precise measurement allows businesses to make faster and more accurate decisions, leading to increased efficiency and minimized waste. The synergy between VSM and RTLS creates intelligent manufacturing systems and internal logistics process management, which can lead to overall improvements in organizational performance. These benefits, accurate tracking and locating of inventory, streamlining material flow, identifying bottlenecks in the logistics chain, and improving process planning, make the combination of VSM and RTLS attractive and effective in the world of modern management and manufacturing.

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BUSINESS PROCESS IMPROVEMENT WITH DYNAMIC SIMULATION SUPPORT

Abstract

In today's corporate environment, it is crucial to continually seek effective methods to optimize operations and achieve competitive advantages. Dynamic simulation, as an innovative tool, offers the ability to systematically model and test different scenarios, enabling organizations to identify key areas for improvement and implement effective solutions.

Key words: Dynamic simulation, Improvement, Process simulation

1. INTRODUCTION

Computer simulation is a statistical-experimental method that replaces the real system with a simulation model on which experiments are executed. With the results of the simulation runs of these experiments, it is possible to generate improvements to the real system. The simulation model is used to draw conclusions that provide insight into the behavior of the elements of the real system that are under observation. [1]
Using simulation, it is also possible to validate results obtained using other methods in terms of stochastic and dynamic effects. The mere experience of creating a simulation model can help in improving the management or structure of an already established management system. Simulation also provides a comprehensive view of the system under study and thus subsequently realize a multidimensional analysis. The simulation model also allows monitoring of system parameters and the interconnection of production control subsystems. A great advantage is the possibility to analyze the behavior of the system in real, accelerated or slowed down time and the possibility to examine different solution options, which leads to minimization of risks, bad decisions, or preparation for unexpected events. [1], [2]
The improvement of production or logistics processes is associated with the implementation of certain measures that change the existing state of the system and always entail a certain risk of a negative outcome. Simulation mitigates this risk by

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allowing the result of the change to be verified on a virtual model, with minimal financial and time costs. [2]

2. PROCESS SIMULATION

Various tasks can be solved through dynamic simulations. They allow to verify the results obtained by other methods, considering stochastic and dynamic influences. In terms of process improvement, simulation can be used to determine the performance of the entire simulated system, the utilization of equipment and operators, the continuous production time, the maximum and average stock levels in the warehouses or the impact of non-delivery on the required production after the improvement has been implemented. It is applicable in a small production shop as well as in a large production plant. Its use brings certainty to innovation decisions and avoids potentially high financial and capacity losses resulting from additional modifications to the real system. [1]

Fig. 1. Example of 3D simulation model

2.1 Advantages of dynamic simulations

Business process simulations provide organizations with many benefits that can have a major impact on efficiency and competitiveness. One of the key benefits is the ability to predict the evolution and outcomes of business processes. Dynamic simulation enables the creation of models (Fig. 1) that consider the various factors that influence processes, thus providing a realistic picture of their operation in real time. [3], [4]
In addition, simulation allows systematic testing of different scenarios and settings, which is important for identifying optimal solutions. By experimenting in this way, organizations can identify and then implement improvements that will lead to better results. It is also possible to identify and assess risks or undesirable scenarios in this way and prepare for them. [2], [5]
Dynamic simulations also increase the flexibility of the organization. They contribute to the ability to react quickly to changes in the business environment and adapt to new conditions. This supports organizations in remaining competitive in today's dynamically changing marketplace. [2], [5]

2.2 Disadvantages of dynamic simulations

Like any method, dynamic simulations have their disadvantages. The biggest ones in terms of business process improvement are [1], [2]:

- Complexity of modelling – creating accurate and relevant models can be challenging and requires special knowledge of processes and their interrelationships.
- Relevant data – processing, acquiring, cleansing, and maintaining large amounts of good quality data for simulation can be time and resource intensive.
- Human factors – implementing changes based on simulation results may encounter resistance from employees to new procedures and process changes.
- Limited modelling accuracy – there is always a degree of abstraction and simplification when creating simulation models, which can lead to limited accuracy of results.
- Dependence on input data – the quality of simulation results is directly dependent on the quality of the input data. If the input data is inaccurate or outdated, this can bias the results and lead to ineffective decisions.
- Time-consuming – Simulations take time to create and evaluate.

Despite these challenges, it remains important to stress that the advantages of simulations often outweigh their disadvantages. With consistent management and the right approach, organizations can leverage dynamic simulations to optimize their business processes and achieve a competitive advantage in today's rapidly changing business environment. [1]

3. CONCLUSION

In this article, dynamic simulation, its use in business process improvement, and its advantages and disadvantages have been described in general terms. The use of dynamic simulation for business process improvement can contribute to the efficiency and competitiveness of a business. Simulations allow to predict and then test and optimize different scenarios, which can help in decision making and minimize risk. However, the disadvantages of simulation should not be overlooked, and sufficient attention should be paid to them to ensure that the results are as relevant and as close to reality as possible.

Acknowledgment

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VIRTUAL REALITY AS A SUPPORTING TOOL IN VARIOUS PARTS OF THE EDUCATIONAL PROCESS

Abstract

Virtual reality (VR) can be a useful tool in many areas. Without a doubt, one of them is education, where VR can be used to demonstrate various circumstances in the safety of the classroom. The presented article proposes two methods of integration of VR into the educational process. The first one uses VR as a tool to create specific assignments, while the second one utilizes VR as a tool for presentation.

Key words: Virtual reality, Education, Virtual environment

1. INTRODUCTION

Virtual reality is a technology known for several decades and its popularity has seen a significant increase in recent years. This is mainly due to the gaming industry, where new high-end games attract ever-larger masses of people. The endless possibilities of simulations and interactions in a virtual reality (VR) environment open the door for the implementation of VR game concepts in industry and education [1,2]. The creation of VR applications directly in the game engine opens wide possibilities limited only by the user's programming skills. This enables the implementation of virtual reality in education at different levels of usability [3-5]. Virtual reality can serve as a support tool but also dig into the foundations of the methodology of various activities.

2. VIRTUAL REALITY AS A SUPPORTING TOOL IN EDUCATION

The presented article presents two of many possible applications of virtual reality in education, while both were tested at the Department of Industrial Engineering, Faculty of Mechanical Engineering at the University of Žilina:

- Virtual reality as an aid in assignment creation.
- Virtual reality as a tool for assignment presentation.

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These methods provide a new approach to the education process, while the novelty of the technology may make students more motivated and invested.

2.1 Virtual reality as an aid in assignment creation

When working on an assignment, virtual reality can provide students with a new perspective. In this case, this approach was used for the manufacturing system design assignment. The goal was to design and manufacturing the system according to set parameters. Fig.1 shows the 2D layout.

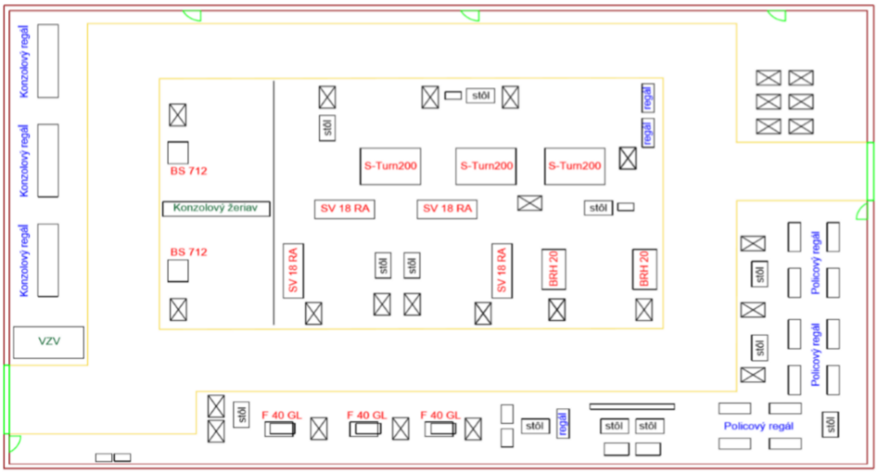

Fig. 1. Created 2D layout.

Subsequently, students used the Unity 3D game engine to create an immersive 3D copy. After initial setup, students imported the necessary 3D models and placed them in accordance with the proposed layout, as shown in Fig. 2.

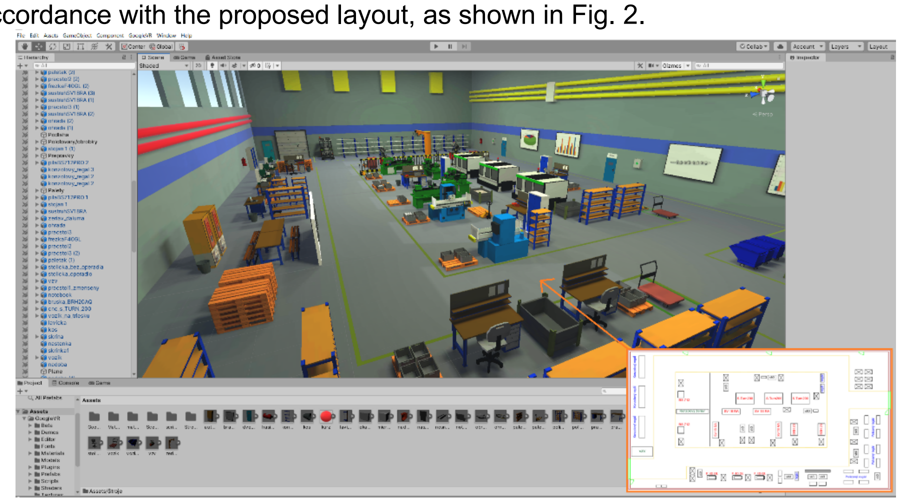

Fig. 2. Creating the 3D environment.

In the end, to elevate the 3D visualization, the design was made compatible with a virtual reality headset. A movement script was imported to allow walking across the manufacturing system wearing the headset. This provides students with a perspective of a worker, possibly identifying the shortcomings of the design. Fig. 3 shows the completed application.

Fig. 3. Exploring the design.

2.2 Virtual reality as a tool for assignment presentation

Another possibility is the implementation of virtual reality in the educational process, specifically for the presentation of assignments. This approach was tested in the classes of designing production and assembly systems. It is a subject of the 3rd year of the summer semester of the bachelor's study of the Department of Industrial Engineering, Faculty of Mechanical Engineering, University of Žilina, where the students' task is to design the initial and improved version of the production layout in the VisTable software according to the specified parameters. Fig. 4 shows the design created by students in the VisTable software.

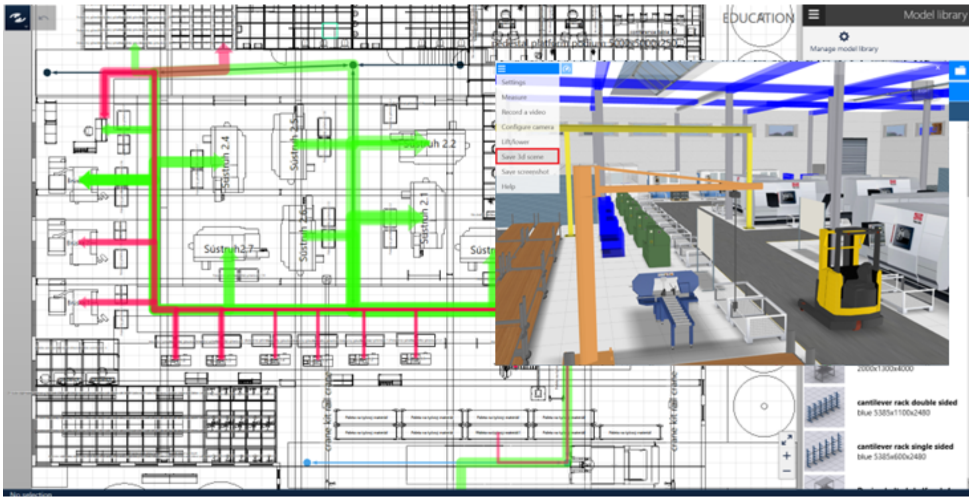

Fig. 4. Proposed design.

In the end, instead of a regular PowerPoint presentation, students imported the 3D model of their design into Unity 3D and similarly to the previous chapter, made it compatible with virtual reality. They created an immersive virtual environment that was used to present their assignment. Subsequently, students would put on the virtual headset and walk around their design to show all the important parts, as shown in Fig. 5. In the meantime, other students would watch their movement on the screen of the monitor. While presenting, observing students would ask questions about the assignment or put on the headset themselves. This approach provides a new way of assignment presentation, that is more attractive and motivating to students.

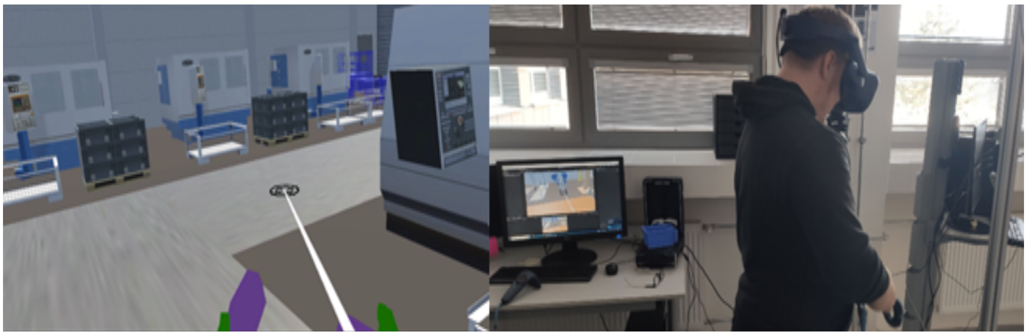
Fig. 5. Presenting the assignment.

3. CONCLUSION

In conclusion, the utilization of virtual reality is on a steady rise, while its potential in education becomes more and more apparent. Presented two methods are just the tip of the iceberg and many new approaches to education using virtual reality will be proposed in recent years. It is important to follow these trends to ensure that the quality of education is always a priority.

Acknowledgment

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IMPROVING ASSEMBLY PROCESSES THROUGH SIMULATION

Abstract

Currently, manufacturing companies face challenges in rapidly implementing changes without sufficient appreciation. Digital simulation technologies in Industry 4.0 enable efficient control, process optimization and production increases. The simulation mimics system behavior, identifies bottlenecks, and optimizes workflows. It accentuates the importance of involving designers in simulation projects for better use of these tools.

Keywords: Digital simulation, Industry 4.0, Process optimization, Assembly line

1. INTRODUCTION

Manufacturing companies face pressure to implement changes quickly without sufficiently evaluating the advantages and disadvantages, which can cause problems and a decline in performance [1]. With the growing need to improve performance and quality, the demand for changes increases. Digital simulation technologies, as part of Industry 4.0, make it possible to control and optimize processes efficiently, reducing costs and increasing production [2,3]. Computer simulation mimics system behavior, helping to identify bottlenecks and optimize work layouts without interfering with the real system [4]. Simulation can encounter communication barriers between designers and simulation specialists [5]. Involving designers in simulation projects reduces these problems because they better understand and use simulation systems effectively. This approach is beneficial for project teams in companies using simulation to improve assembly processes and evaluate decisions using software like Tecnomatix Plant Simulation.

2. MATERIALS AND METHODS

Modelling and simulation have become key tools in solving various tasks where conventional estimation is no longer sufficient. These techniques are applied in a wide

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range of environments, including airports, hospitals, ports, mining areas, amusement parks, call centers, supply chains, manufacturing, and more. However, they are most pronounced in industry, where huge sums need to be invested in production capacities and where results need to be pre-verified before projects can be launched in order to maximize the effect. The production area includes both production and logistics. Simulations are used to optimize production and logistics processes, test new approaches, and plan the deployment of workers. The application of these techniques in the industry is projected to continue to grow, helping the company improve efficiency and innovative processes, especially in manual assembly.

2.1 Simulation tool

The implementation was carried out according to the simulation methodology for the manual assembly workplace.

The simulation project begins with the analysis of the real system, defining the problem and the objectives of the simulation. It is important to gather enough information about the means of production and the knowledge of workers. This is followed by the creation of an abstract logical model, which is validated on a computer. After validation, the model shall be validated and pilot runs shall be carried out. At the next stage, experiments with changing parameters are planned and carried out. The results of the experiments are evaluated and, if satisfactory, the changes are applied to the real system. Where there are differences between objectives and results, the model shall be adjusted. The Tecnomatix Plant Simulation 15.2 software tool was used as a tool.

2.2 Description of the simulated process

In the previous chapter, the methodology described above was used to conduct a simulation study on an assembly line where the rear seats of a passenger car are manually assembled.

This is a process where heating, a pressure sensor, cables, a housing and an isofix are installed in turn. The initial hypothesis is that there is a division of activities and fewer workers, with the output from the workplace comparable to the current one. The layout of the selected material flow assembly process is shown in Fig. 1. The selected assembly process and performed activities do not have set times for operations, but are determined by the tactical of the customer's line. Therefore, there may be a situation where the tact in the workplace is higher or lower. For each workplace, a workflow is defined guaranteeing the required product quality. The static position of workplace materials and buffers is also defined. At the workplace, various variants of seats are mounted, differing in foam, cover (vinyl-semi-leather, leather, textiles) and heating. The assembly procedure is the same for all types of products, except for the installation of heating, which takes longer. The material supply is considered 100% reliable. The assembly process includes the preparation of materials and workplaces, the installation of the upper part of the seat and the pairing of parts in the E04_2 workplace.

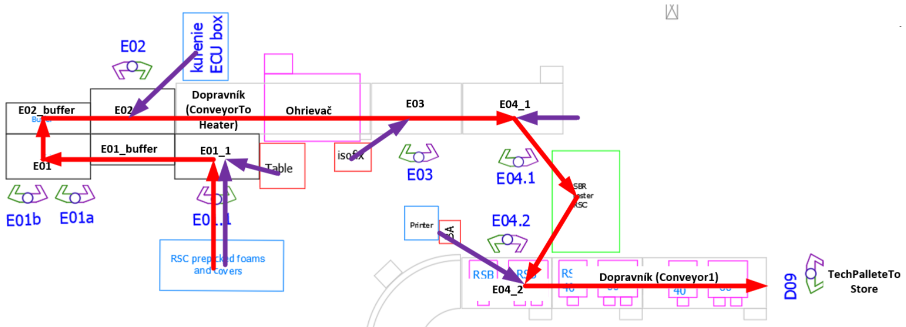


Fig. 1. Layout of manual assembly and material flow workplace

Synchronizing these processes is key because non-synchronization causes delays. The finished parts are loaded onto a technological pallet for automatic storage. When creating a simulation model, the results are predictable as the inputs are precisely defined. The accuracy of the collected data is verified and validated. Data collection is based on the objectives of the simulation project, with an emphasis on abstraction and reduction. Products differ in the foam used, cover (vinyl-semi-leather, leather, textiles) and heating. The material flow is shown in Fig. 1. The main flow of products is red, the installation points of the material are purple. The duration of activities in the workplace was directly measured in production, and a triangular distribution was selected for the data.
The installation is divided into several activities: take foam filler, stick the pressure sensor, apply heating (if necessary), cover with a cover, attach the cover to the seat, stretch the cover, attach it to the bottom of the seat, connect the heating unit and cables, straighten, warm up, install isofix, iron and check, assign a label for quality control, final inspection and loading.

3. RESULTS AND DISCUSSION

The created simulation model contains a line model, where the entire process of product assembly takes place. First, a raster from a CAD file was inserted, on the basis of which objects were modeled to their actual dimensions for the correct distances and constraints. After objects were inserted and modeled, parameters were defined for objects, workers, and products with logical critical rules. The model was verified and validated using order sheets, with a difference with the real system of +/- 0.38%. The simulation model in 2D and 3D graphics is shown in Fig. 2. For the design of experiments, it is necessary to consider whether it is possible to produce faster and reduce the number of workers without affecting the performance of the line. The analysis of the results includes graphs of worker utilization (Fig. 3(a)) and workplace (Fig. 3(b)). There are two bottlenecks on the production line with the highest clock times, E01 and E04_2. The graph of the load on workplaces (Fig. 4) shows that the E04_2 blocks the measuring station and secondary E04_1, with E02 and E03 also affected by E04_2. E01 blocks E01_1. The current output is 30.74 pcs per hour. The experiments examined combinations of the number of employees, the division of work activities and the ability to fulfill the tact of the customer line. First, experiments were conducted to merge workplaces. Tab. 1 shown experiments conducted to identify the possibilities of merging workplaces and their activities

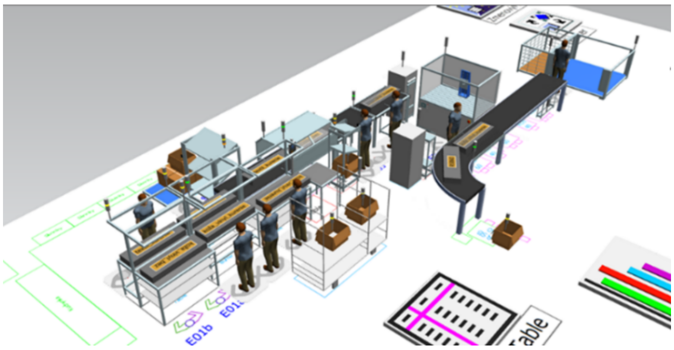


Fig. 2 Layout of manual assembly and material flow workplace

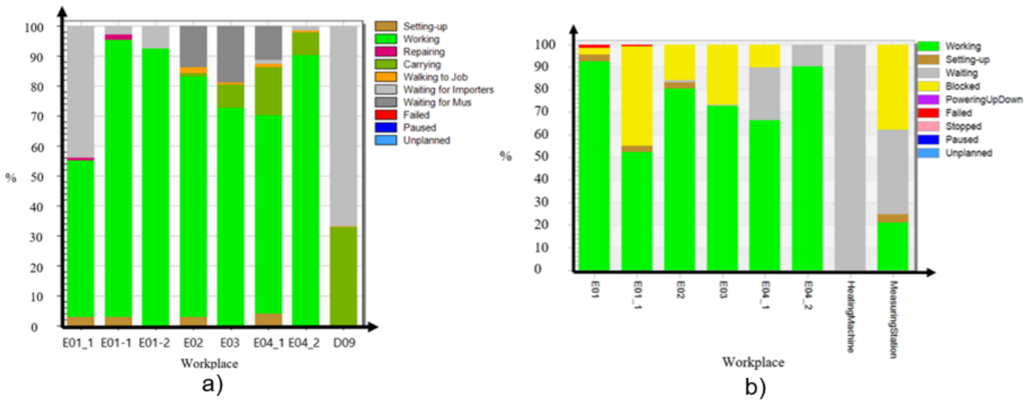
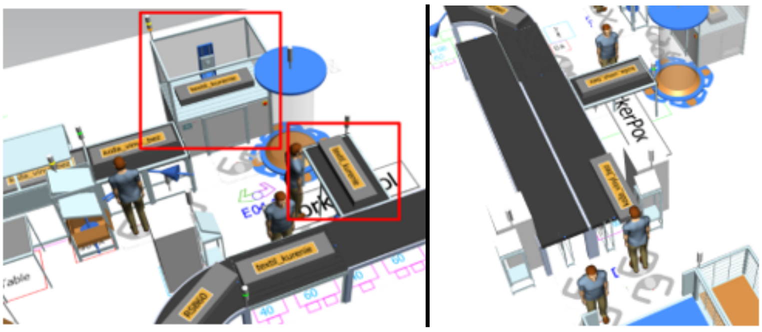


Fig. 3. a) Graph of current workload; b) Graph of current workplace utilization

Tab. 1 Experiments conducted to identify the possibilities of merging workplaces and their activities

Experiment number	Workplaces whose activities are merged	Output [Pcs./hour]
Exp. 1	E01_1 and E02	**20.68**
Exp. 2	E01_1 and E03	**5.20**
Exp. 3	E01_1 and E04_1	**20.30**
Exp. 4	E01_1 and D09	**28.87**
Exp. 5	E02 and E03	**19.06**
Exp. 6	E02 and E04_1	**15.77**
Exp. 7	E02 and D09	**22.80**
Exp. 8	E03 and E04_1	**18.00**
Exp. 9	E03 and D09	**25.18**
Exp. 10	E04_1 and D09	**24.06**
Exp. 11	E01_1 and E02	**20.68**

From the resulting statistics, the minimum clock of the customer service line was achieved only when merging activities at E01_1 and D09 sites, which is not enough for a faster cycle of the line. The potential lies in testing the division of activities. The following experiments were aimed at dividing activities for line balancing.
Experiment 12: The same number of workers, a worker from E02 helps E01_1, and one activity from E01 is transferred.
Experiment 13: The same number of workers, a worker from E02 helps to E01_1, one activity from E01 is moved, and switching the measuring station and E04_1.
Experiment 14: Same number of workers, switching of measuring station, and E04_1.
Experiment 15: Changing the number of workers, a worker from E02 helps to E01_1, one activity from E01 is moved, changing the measuring station and E04_1, and removing the worker from the E04_2 with moving his activities to D09. The toss is shown in Fig. 4.



a) b)

Figure. 4. a) Illustration of positions after replacing the Measuring Station with E04_1; b) Display of the position of the additional conveyor

Experiment 16 is an experiment without changing the number of workers. An employee E01_Instal_LSHog from position E02 helps at the workplace E01_1, where workplace E01 has been moved and a measuring station with E04_1 has been rescheduled. At the same time, conveyor and E04_2 activities are transferred to D09_1 and D09_2. An illustration of the location of the additional conveyor is shown in Fig. 7.
Tab. 2 shows experiments and their results.

Tab. 2 Experiments and their impact on hourly performance

Experiment number	Output [Pcs./hour]
Exp. 12	**30.74**
Exp. 13	**30.27**
Exp. 14	**30.14**
Exp. 15	**31.04**
Exp. 16	**32.87**

Tab. 2 shows two experiments, 15 and 16. If we consider reducing the number of workers and at the same time the highest possible performance, the result from experiment 15 is optimal. If we are considering streamlining the line for an even faster cycle of the customer line, the solution from experiment 16 is the best.

4. CONCLUSIONS

In today's competitive environment, a company's success depends on the ability to adapt, which is essential to satisfying customers. Efficient processes increase production and reduce resource waste. In assembly processes, it is important to balance line times and minimize the impact of bottlenecks on final performance. Computer simulation helps to identify bottlenecks and subsequent problems. A validated simulation model allows decisions to be verified without interfering with the real system, thus minimizing negative impacts on production and costs.
The article describes the use of simulation in a simulation study and the results obtained. The study used the Siemens Tecnomatix Plant Simulation 15.2 tool to increase assembly line efficiency. The company's hypothesis was that a new division o workers and activities would increase performance. The proposed variants confirmed that reducing the number of workers by one increases performance by 0.94% and meets the requirements for medium and slow cycle lines. A faster clock speed of the hotline can be achieved without reducing the number of personnel and performance can increase by 6.89%. This methodology is suitable for companies that need to verify optimization solutions associated with investment costs.

Acknowledgment

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THE PREDICTIVE MODEL AS PART OF AN INTELLIGENT MAINTENANCE SYSTEM

Abstract

The prediction model is explained in this work as a crucial component of intelligent maintenance systems. As part of Industry 4.0 and Industry 5.0, maintenance systems must be continuously improved, and prediction models play a crucial role in this regard. We cannot develop intelligent maintenance systems that support the creation of fluidity in industrial processes without implementing predictive models.

Key words: Predictive model, Maintenance, Industry 4.0

1. INTRODUCTION

The intelligent maintenance system is a system that uses collected data from machines to predict and predict possible failure. The occurrence of machine failures can be costly and even catastrophic. There had to be a machine behavior system and preventive maintenance instructions. The analysis of machine behavior is made possible by intelligent sensors, data acquisition systems, data storage and transmission capabilities, and data analysis tools. This is the same set of tools developed for forecasting. An intelligent maintenance system is a system that uses tools to analyze data, support decisions, and predict and prevent possible machine failure. Recent advances in information technology, computers, and electronics have facilitated the design and implementation of such systems. [1]
The intelligent maintenance system represents an innovative approach to managing and monitoring the condition of equipment, machines and information flows. This system uses advanced technologies such as sensors, data analysis, artificial intelligence and machine learning to predict, diagnose and optimize maintenance. Its key elements are:

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- Smart sensors: Maintenance systems use sensors to collect data on the construction, performance and operating conditions of equipment. These sensors can monitor various parameters such as temperature, pressure, vibration and many others. This data is then analyzed to detect possible problems or potential malfunctions.
- Predictive Maintenance: Intelligent maintenance systems use data analysis to predict future failures or outages. In this way, maintenance can be carried out at the right time, before serious problems occur, resulting in reduced costs and downtime.
- Process Optimization: These systems constantly analyze operational data and evaluate the efficiency and reliability of processes. Based on this data, they can suggest improvements and optimize maintenance procedures, leading to increased productivity and reduced energy and material consumption.
- Artificial Intelligence and Machine Learning: Intelligent maintenance systems often use artificial intelligence and machine learning algorithms to automatically identify patterns and anomalies in data. These technologies are able to learn from the acquired data and continuously improve in fault prediction and diagnosis.
- Cloud Technologies: Many intelligent maintenance systems use cloud technologies to store and process large volumes of data. These platforms allow easy access to data from any location and ensure its safe storage. [2]

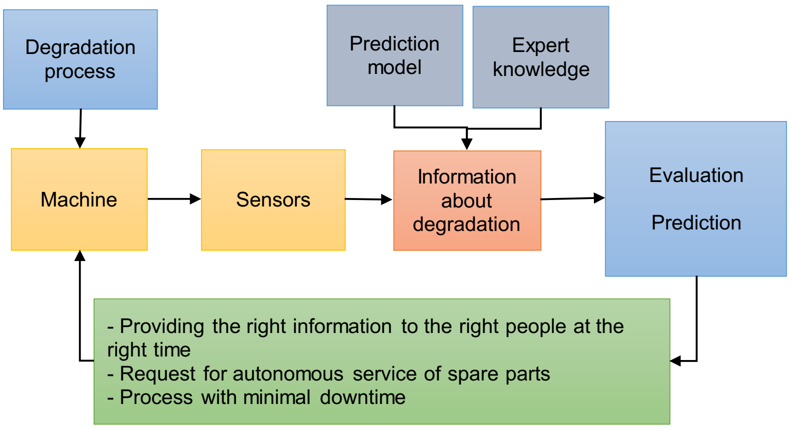

Fig. 1. Intelligent maintenance system [2]

Intelligent maintenance management relies heavily on solving computational problems, the core of which are prognostic and optimization algorithms. In some applications, the amount of collected data is voluminous and high-frequency, which requires efficient data pre-processing and computing power. [3]

2. THE PREDICTIVE MODEL

The prediction model is an integral part of intelligent maintenance systems. It is based on predictive maintenance, which tries to address the problem of correctly determining the moment for maintenance using advanced statistical methods and artificial intelligence. The maintenance of each equipment, which is based on predictions, is assessed and planned based on the current state of the equipment, and through various predictive models, an effort is made to estimate the date and time of failure. [4] Subsequently, it is possible to shorten or extend the maintenance cycles according to the condition of the given equipment.
In order to be able to accurately determine the condition of the device, it is necessary to use various diagnostic procedures and devices. Classic preventive maintenance can be carried out even without artificial intelligence and smart sensors. Basic diagnostic tools such as ultrasonic measurements, oil quality, etc. are used for this type of maintenance. Such diagnostic operations are usually expensive and cannot always be carried out during the operation of the device. [5]
Intelligent sensors and advanced prediction models, which are capable of fully automating most of these diagnostic activities, bring a fundamental breakthrough. The introduction of such automatic monitoring contributes to a drastic increase in the accuracy of prediction and a reduction in the need for costly diagnostic checks. Automatic monitoring can also be deployed not only on the most critical devices, but on all important machines [6]. Thanks to constant monitoring, it is also possible to identify phenomena and the state of the machine, which would not be possible to identify in a traditional way.
The prediction model combines the current maintenance system and the intelligent maintenance system at the enterprise level (Fig. 2). It must always be based on the current state of the device and historical data on the given device. The outputs from the predictive model enter the intelligent maintenance system as information that must be incorporated into the automatic reporting of faults at the right time and to the right people, automatic planning of maintenance activities and automatic inventory of tools and spare parts.

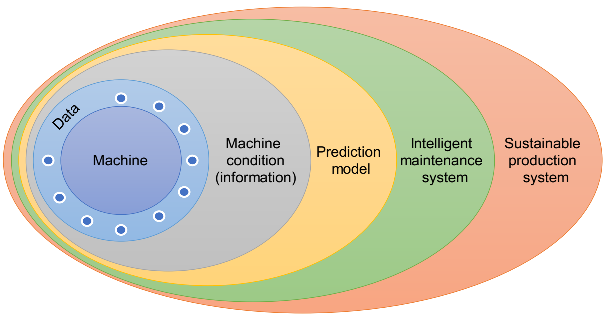

Fig. 2. The position of the intelligent maintenance system with respect to the machine and the sustainable production system [own processing]

In the basic structure there is a stand or a device that performs its function and maintenance is performed on it. We can collect data from this machine using smart

sensors, overall equipment effectiveness (OEE), etc. This constitutes the overall condition of the machine or production equipment. Using data collected from the machine and individual states over time, we are able to predict its future state according to the prediction model. These future states of all machines and equipment enter as input data for an intelligent maintenance system that automatically creates and optimizes maintenance plans at a company-wide level, taking into account all aspects of the maintenance strategy, maximizing the overall efficiency of the equipment, minimizing maintenance costs and thus helping the sustainability of the production system.
The success of the prediction model depends on three factors, which are disposition of the right data (relevant, sufficient, quality), correct definition of the problem and correct evaluation of the prediction. [7]
Since the operational life of production machines is usually several years, the historical data should go back far enough to correctly reflect the degradation processes of the machines. In addition, other static information about the machine is also useful, such as data about the machine's properties, its mechanical properties, typical usage behavior and environmental operating conditions.

3. CONCLUSIONS

Once we have all information, it is possible to decide which modeling strategy best fits the available data and desired output. This thesis deals with the design of a regression prediction model to predict the remaining life of a machine.
For this scenario we need static and historical data and labeling of each event. In addition, several events of each failure type must be part of the data set. Ideally, we prefer to build models when the degradation process is linear. Furthermore, we typically only model one type of "path to failure." If multiple failure types are possible, one dedicated model should be created for each of them. In manufacturing, regression can be used to calculate an estimate of the remaining life of a machine.
In the case of regression, the most commonly used machine learning algorithm is linear regression, which is relatively quick and easy to implement with output that is easy to interpret. An example of linear regression would be a system that predicts temperature, since temperature is a continuous value with an estimate that could be easily trained.
Regression is used when the data has a quantitative nature (eg temperature, weight), so it is most suitable for creating predictive models using sensors.
The prediction model is able to detect the impending failure of a specific machine or its parts. Early detection is a fundamental element to effectively plan maintenance activities without limiting other parts of the business such as production or logistics.
Another contribution of the prediction model to the intelligent maintenance system is the automatic reporting of faults to the relevant maintenance personnel according to individual modules and the severity of the detected problem. Thanks to communications with MES and human resources, the prediction model is able to report the obtained prediction of adverse conditions operatively, automatically and online.
As long as the cooperation between the intelligent maintenance system and the intelligent manufacturing system works in all their parts, including production and maintenance planning, the prediction model can automatically plan individual maintenance activities according to the prediction along with all available resources. The problem occurs in the following cases:

- An abnormality is detected on the machine and an appropriate model is not used to detect the specific type of impending failure.
- An abnormality on the machine is detected and the specific type of failure is known, but the qualification matrix of the maintenance workers is not created, so the prediction model "does not know" to whom to send the notification.
- An abnormality on the machine is detected and the specific type of failure is known, a maintenance qualification matrix is prepared, but spare parts are not available at the scheduled time.
- An abnormality on the machine is detected and the specific type of failure is known, a maintenance qualification matrix is created, spare parts are available at the scheduled time, but the production will not release the production stand for maintenance activities.

As long as all connections are treated, the prediction model is able to work effectively even with automatic maintenance activity planning.

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ENHANCING THE WORK ENVIRONMENT: THE SIGNIFICANCE OF ERGONOMICS AND REST STRUCTURE IN BUSINESS PROCESS IMPROVEMENT

Abstract

This article aims to determine the general relationship between human factors and the improvement of business processes. This work specifically examines the impact of the rest structure model of employees' workdays on process improvement within enterprises. Initially, the article addresses the development of the subject matter, including the history of business processes and their interaction with human factors and ergonomics. Subsequently, it conducts a literature review on the topic, facilitating a deeper analysis and examination of the current state of the issue worldwide. The core of the paper describes the integration of ergonomics and business processes, with a particular focus on the impact of the rest structure model of employees' workdays on the enhancement of business processes.

Key words: Industrial engineering, Ergonomics, Business processes, Well-being

1. INTRODUCTION

Ergonomics, in general, can be understood very broadly. It can encompass everything from workplace improvements and working in extreme environments and conditions to areas such as the human mind, work organization, stress, motivation, and even comfort and relaxation in the workplace [1]. In general, it can be said that the ergonomic analysis of a given system is necessary for almost all aspects of work related to the humanization of labor and human activity in general [2,3].

Regardless of the size of the company, industry, or field, ergonomics is still not a requirement in most enterprises. However, it is important to consider aspects related to the humanization of work because the positive relationship created between a person and their work and the activities they perform is currently very important, though it is still not commonplace. Therefore, topics such as relaxation methods within the work process and the interaction between work activities and relaxation should be increasingly brought to the forefront to improve working conditions and eliminate

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the occurrence of occupational diseases. Non-adaptive ergonomic workplaces can cause not only physical but also psychological illnesses, so it is important to focus on easing the work of employees and also on their workday organization to eliminate fatigue and monotony at work. [4,5]

2. DEVELOPMENT OF THE SUBJECT MATTER

The histories of business processes and ergonomics are distinct, each with its own development trajectory. However, both fields are closely related to the evolution of management and human labor. This connection underscores the importance of improving workplace environments and processes to ensure efficiency and employee well-being. Ergonomics began to establish its roots in the 19th century, in response to growing industrial development. By the 20th century, ergonomics emerged as a separate scientific discipline, focusing on the study of work environments, productivity enhancement, and the prevention of workplace injuries, especially during the interwar period. After World War II, ergonomic principles were increasingly applied in workplaces and industries. [6]

The concepts related to business process improvement also emerged during the Industrial Revolution, driven by the quest for greater production efficiency. During this period, Frederick Taylor advocated for precise measurement of work and task performance, as well as the improvement of business procedures. In the 20th century, new business process methodologies such as Six Sigma and Lean Manufacturing began to develop. Post-World War II, process improvement became a key component of industrial recovery, with techniques and quality management methods being applied to enhance efficiency and competitiveness. [7]

According to Parsons et al. [8], a significant link between ergonomics and business process improvement began to form when:

- Ergonomic research started to focus on optimizing the work environment to improve employee performance and well-being.
- Business process improvement began to include not only technological innovations but also considerations of human processes and factors, aiming for more efficient and humane management.

Overall, both ergonomics and business process improvement have evolved with the primary goal of creating better work environments and optimizing processes to achieve efficiency and quality in work. Ergonomics has focused on the individual worker's experience, while business process improvement has targeted broader organizational procedures. Today, these two fields are closely integrated within a comprehensive approach to managing work processes and management. [9,10]

3. LITERATURE REVIEW

In the study by Brito et al. [11], the authors present an attempt to develop a tool that incorporates operational measures of lean practices combined with safety and ergonomic conditions in the workplace or on the production line. This operational tool aims to assist researchers and professionals in prioritizing and evaluating lean manufacturing implementations about ergonomic and safety conditions through an integrated approach. It helps experts (technicians and ergonomists from manufacturing companies) assess the implementation of lean manufacturing principles and safety issues in their processes. It also allows managers to evaluate their businesses and identify priority areas for improvement according to predefined company goals.

In their article, Bolis et al. [12] present the results of an academic research project that links ergonomics and work-related issues with the theme of sustainability. The research question addressed in the article is: How can companies improve their corporate and decision-making processes to enhance employee well-being through policies that integrate ergonomic considerations, corporate sustainability, and business process improvement? The defined problem in this study was that the integration of ergonomics is likely separated from strategic functions and human resources functions, which are crucial for establishing the internal-social component of corporate sustainability. The result of this research asserts that corporate sustainability requires a new approach, specifically the improvement of business and decision-making processes by including and recognizing the central role of workers in creating sustainable measures. If corporate policies focus on employees, this creates an opportunity for the integration of ergonomics as a tool contributing to organizational sustainability, ensuring improved employee performance, productivity, quality, and health within business processes.

The study by Doel et al. [13] examines industrial processes where rigorous monitoring of the physical process of product creation and employee safety is essential to ensure the smooth operation of facilities and manufacturing processes. The authors used Six Sigma methodology as a set of techniques to reduce the number of defective parts and ergonomic analyses to monitor the quality of manufacturing processes through employees. This study focused on the production process of window and patio door frames. After conducting capability reports on the analyzed samples, it was found that the main causes of defects in the process were dimensional deviations and variability in the manufacturing process within punching machines. Additionally, the dimensional deviations caused ergonomic stress for punching machine operators, leading to risk studies analyzing injuries within this process. Solutions were proposed and implemented using the Six Sigma methodology to resolve issues in the process. These changes significantly improved the efficiency of the manufacturing process and reduced ergonomic strain on operators. Potential long-term solutions include changing the manufacturing environment or automating the punching machine to ensure improved extrusion processes and worker safety.

The outcome of the literature review on this topic illustrates that, in general, the relationship between ergonomics and the role of humans in the manufacturing system has a significant connection to improving business and manufacturing processes. These are two interrelated areas that go hand in hand, as ergonomics is an integral part of steps taken to improve business processes.

4. INTEGRATION OF ERGONOMICS AND IMPROVEMENT OF BUSINESS PROCESSES

This chapter will describe the integration of ergonomics and business process improvement, as these two fields are inherently connected and crucial for creating a productive and efficient work environment. The improvement of business processes and ergonomics, specifically the role of humans in manufacturing systems, are vital areas that interrelate seamlessly, leading to enhanced productivity and efficiency in the workplace.

4.1 Ergonomics and its purpose as part of the working environment

Ergonomics focuses on designing the work environment to be efficient, comfortable, and safe for the human body, ensuring that the work is natural for people and meets their needs. The humanization of work within the workplace encompasses various aspects such as furniture, lighting, and the placement of tools, and equipment. Ergonomic design can enhance employee comfort, reduce fatigue, and improve overall productivity, whether it be the process itself or the individual worker. When implementing ergonomic solutions, it is crucial to consider the individual needs of employees and their specific job tasks.

4.2 Improving business processes as a tool to create an effective working environment

Business process improvement involves the identification, analysis, and enhancement of current work processes within an organization. The primary objectives are to reduce costs, increase efficiency, and improve the quality of desired outputs. When improving work processes, it is essential to consider the following steps:

- Identify Processes: Define the main processes within the organization and subsequently identify areas where improvements can be made.
- Analysis and Evaluation: Analyze the current state of processes and evaluate where improvements can be achieved. This may include streamlining procedures, eliminating redundant steps or activities, or introducing new technologies.
- Implementation of Changes: Implement the proposed improvements and monitor their outcomes. This often involves the introduction of new technologies, automation, digitization, robotics, and the enhancement of information flow.

The integration of ergonomics with business process improvement can lead to a harmonious and efficient work environment, which positively impacts employee satisfaction and the overall performance of the organization.

5. IMPACT OF EMPLOYEE DAILY ORGANIZATION MODEL ON BUSINESS PROCESS IMPROVEMENT

The model of structuring employees' daily rest has a significant influence on enhancing business processes. Properly managed balance and rest between leisure time and work could positively affect employee well-being, productivity, and overall organizational efficiency. Cohesion can be achieved through the following means:

- Enhancement of Efficiency and Concentration: Employees who have the opportunity to adequately rest tend to return to work more focused and productive. Regular rest contributes to improving employees' mental well-being and their ability to tackle tasks more effectively, which significantly impacts the smoothness of business processes.

- Reduction of Work Stress: A suitable rest model for employees during the day helps in reducing work-related stress and prevents employee burnout. The elimination of work stress in the organization leads to higher work morale, increased employee satisfaction in the workplace, and better teamwork, reflected on the performance of business processes.
- Improvement of Mental and Physical Well-being: Employees who have sufficient time for relaxation or physical activity during their workday may experience better mental and physical well-being. Typically, this leads to lower absenteeism, higher resilience to stressful situations, and increased energy levels, subsequently stabilizing business processes.
- Promotion of Innovation and Creativity: Adequate rest time for employees promotes innovation and creativity. Consequently, employees are more likely to come up with new solutions and ideas when they have enough space for rest and relaxation of their minds.
- Enhancement of Engagement and Work Morale: Companies that prioritize the balance between their employees' private and work lives often observe higher work morale and engagement among their employees. Employees develop a positive attitude towards work and tend to be more loyal and motivated towards their workplace and job, contributing to the smoother functioning of business processes.

The integration of the model of structuring employees' rest into the work environment can be advantageous for organizations not only in terms of employees' well-being and prosperity but also in terms of improving business processes. This can create an environment where employees feel supported and motivated, which manifests not only in the overall performance and success of the organization but also in the well-being of employees.

6. CONCLUSION

The primary objective of this study was to describe ergonomics, the model of structuring an employee's daily rest, and the impact of these aspects on business process improvement. From the article, it is evident that the model of structuring an employee's daily rest could have a significant impact on enhancing business processes. For instance, when work and rest are properly balanced within the workday, it can positively influence the productivity of both the employee and the organization, employee well-being, and especially the overall efficiency of the organization. Additionally, it enhances employee work morale and creativity in generating ideas and innovations.

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