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STROJNÍCKA FAKULTA
KATEDRA PRIEMYSELNÉHO INŽINIERSTVA

and

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Katedra Inżynierii Produkcji, Wydział Budowy Maszyn i Informatyki,
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so sídlom v Trnave, Slovenská technická univerzita v Bratislave

INVENTION FOR ENTERPRISE

InvEnt 2023

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CONTENTS

CONTENTS

Vsevolod BASTIUCHENKO[1], Vladimíra BIŇASOVÁ[2], Michaela BODINGEROVÁ[3], Marta KASAJOVÁ[4]

APPLICATION OF ADVANCED TECHNOLOGIES IN THE CREATION OF ERGONOMIC SOLUTIONS

Abstract

The Covid-19 pandemic was one of the main reasons why researchers and experts from around the world decided to develop a technology to assess working positions without the use of any sensors. When assessing work positions, it was essential that an assessor, often an external service, observe the worker at work in real time, that is, be physically close to them. This paper deals with an introduction to Kinetica Labs' sensorless technology for the assessment of working positions in ergonomics. Extensive advances in technology continue to improve our working and personal lives. From the large of technologies currently available, among the most attractive are those that operate on the principle of artificial intelligence. Researchers and innovators around the world see the potential in such technology and have found applications for ergonomics.

Key words: Advanced technologies, software, ergonomic solutions

1. INTRODUCTION

There are currently a number of technology and software solutions for ergonomics assessment. Among the best known and most commonly used software solutions are those from Siemens. Specifically Tecnomatix Jack or Process Simulate Human. These are tools through which we can create a working environment, insert into that environment anthropometrically and biomechanically accurate human model. Subsequently, it is possible to perform the most widely used ergonomic analyses such as RULA, OWAS, NIOSH, LBA, etc. Another well-known software solution is the CERAA application from Asseco CEIT, a.s. [1]. In addition to software solutions, various technological solutions are available on the market, that can be used to assess working positions. These are divided into sensor-based and sensorless. An example of a sensor-based technological tool is, for example, Microsoft Kinect. This tool can also be connected to the Tx Jack software [2].

2. LITERATURE REVIEW

The latest sensorless technology for use in ergonomics is a product from Velocity EHS called Kinetica Labs. A tool can be used to assess a worker without the need for a sensor to sense the worker as they move. This product works with regular videos taken with a camera or smartphone. The processing of the captured data is done through computer vision algorithms [3].

Computer vision is a field of artificial intelligence that trains computers to interpret and understand the visual world. It is used to process visual input such as a photograph, video or live footage from a camera or smartphone. There are currently several known uses of computer vision. One example is fingerprint recognition or recognition of facial recognition [4].

Evaluating working positions with this technology is very simple. The first step is to take a video of the worker performing the work activity. The worker must be filmed perpendicularly to avoid distortion of

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the results. The filming can be done with a camera or with a smartphone. The recorded video is then uploaded to the Kinetica Labs app where the evaluation will take place. Through computer vision algorithms, the app recognizes the worker in the video and assigns them a simple skeleton composed of lines. Each line represents a different part of the worker's body [5].

Each of the lines is represented by a color. The color scale represents the colors of the semaphore, with green represents an acceptable working position where there is no risk of the worker health and no corrective action is required. The yellow color represents a conditionally acceptable working position where increased attention is required, and red represents an unacceptable position where the worker is at high risk of developing a health problem in which case corrective action is already required.

A visualization of the results can be obtained by means of a bar chart. The user can can generate either for the whole body or for each part of the body separately. This graph will give the user information for which specific activity how much time the worker stayed in acceptable positions, how much in conditionally acceptable postures and how much in unacceptable postures [6].

The tool from Kinetica Labs is very effective because of its simplicity and speed in collecting as well as evaluating data. Table 1 provides a comparison of sensor, sensorless and manual ergonomics assessment technologies with respect to resources, the process of data collection, processing and evaluation and in terms of difficulty for the ergonomist [7-8].

Tab. 1 Comparison of assessment tools in ergonomics [7]

	Sensor technologies	**Sensorless technologies**	**Manual evaluation**
Sources	• The Ergonomist • technology with sensors • software support for evaluation	• The Ergonomist • Camera • software for processing the captured data • computer	• The Ergonomist • evaluation forms • computer
Process	• Sensor placement • automated data processing • implementation of corrective measures	• filming a worker at work • real-time data collection	real-time monitoring of the worker by an ergonomist entering data into forms analysis and evaluation of collected data
Demands on the ergonomist	An ergonomist must be present in real-time with the worker to deploy and correctly set up the sensors for data collection.	The ergonomist does not need to be present during data collection. A video of a work activity can be made by anyone with a supervisor, even without ergonomic knowledge.	An ergonomist must be present in real time at the worker's side and observe the worker at work.

3. RESULTS

CERAA is an application that can be used to quickly and efficiently assess whether compliance with basic ergonomic requirements with regard to minimizing physical strain and eliminating health problems of workers. Similar to the Kinetica Labs app, it is installed on a tablet or on a smartphone, which serves as an assessment tool. It consists of 4 modules, with the assessment work positions is located in the first module. This app allows you to assess working postures based on legislation that is binding for the country concerned or based on European technical standards [9-11].

The working principle of the application is based on augmented reality. This is represented by a virtual model human. This model is designed to compare the virtual state with the real one. After selecting a specific body part that we want to observe on the worker on the screen of a tablet or smartphone a scale will appear on the screen that helps to read the degrees of the worker's deviation from the neutral position of each joint (Fig. 1).

This scale can be used to determine whether the worker is in an acceptable position (green), conditionally acceptable (orange) or unacceptable position (red) with a given body part.

The CERAA assessment is carried out by requiring the assessor to physically observe the worker at work in real time and overlay a virtual model on top of the worker in order to read the angle of deflection of the body part being assessed. To visualize the data, the application allows for the creation of a real-time photograph, which is often very challenging due to the worker's mobility.

Fig. 1 Demonstration of CERAA workstation assessment [10]

The potential to improve working postures in this application is possible through sensorless sensing, as used by the Kinetica Labs application. Because of the features of such technology, it will be possible to perform the assessment much more efficiently. Table 2 shows the steps that need to be taken when assessing working positions through the CERAA application and equally through the computer vision technology in the Kinetica Labs application.

Tab. 2 Sequence of steps in ergonomics assessment with CERAA and Kinetica Labs [11]

CERAA application	**Kinetica Labs**
1. Starting the module	1. Starting the model
2. Selection of input characteristics	2. Making a video recording of the work activity
3. Selection of the body part to be monitored	3. Uploading the video to the application with automatic evaluation of the results
4. Tracking the worker via tablet or smartphone screen	5. Creating a report
5. Taking a photo to capture the worker's location	
6. Measurement of the worker's dwell time in the working position	
7. Creating a report	
8. Repeat steps 3-7 for each body part separately	

As can be seen from Table 2, the sequence of steps differs between the mentioned applications. With the CERAA application, there are many more steps to be performed in the assessment than with the computer vision assessment in Kinetica Labs.

A major advantage of Kinetica Labs is that the ability to upload a video recording of the work activity speeds up the assessment considerably. The video recording of the work activity allows you to stop the video recording at any point and read off the type of working position; it is also possible to determine the length of time the worker stays in a particular position or even to observe several parts of the body at the same time. Whereas with CERAA assessment, a sequence of multiple steps must be performed for each body part separately, which slows down the assessment process considerably.

4. CONCLUSION

The first step is to do a survey of available application programming interfaces (APIs) that will provide the functionality for recognizing the different body parts. The API will be selected based on several parameters such as license price, data processing quality, etc. The selected API must be compatible with the Unity software. This software will be used to develop a new way of evaluating work positions, especially in terms of graphical design. If the selected API is not directly compatible with the Unity software, a plugin (add-on module) must be developed to extend the functionality of this software and ensure the necessary compatibility.

The next step will be to integrate the selected API into the Unity software. The integration is an import of all the files needed to create the code that will be used in the project. Then, an algorithm needs to be created to transform the data from the video. In this step, a program will be created through which it will be possible to transform the output data into a form usable for the needs of the evaluation and visualization methodology. Subsequently, it is necessary to create an algorithm to process the data from the video and integrate the evaluation into reports, i.e. to select the data that we want to be the output of a given evaluation.

At the same time, with the creation of the algorithm for transforming and processing the data from the video to the integration of the evaluation into reports, the visualization of the application is created. Buttons, window logic, data visualization are created. Then it is possible to start testing the proposed evaluation methodology and the functionality of all the controls in the application. If the testing went well, the last step is to create an installation file in apk format. file to distribute the app to Android devices and create an X code project to distribute the app to iOS devices.

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THE BENEFITS OF DIGITAL TECHNOLOGY FOR LOGISTICS WORKERS

Abstract

The implementation of digital technologies in logistics can be viewed from an economic perspective, which leads to more efficient and reliable processes, but also from the perspective of ergonomics and Industry 5.0. The use of digital technologies is beneficial for workers in many areas, whether it is the reduction or complete elimination of load handling, which is closely linked to the development of musculoskeletal disorders, or Overall, innovations in Industry 5.0 are more focused on people and their needs for skills and knowledge, thanks to technology. Conversely, technology is taking the place of goods handling or replacing physical handling with automated handling. The paper focuses on a specific company and describes the technologies introduced as well as their benefits for the workers and the company itself. The paper concludes with a description of future trends in logistics.

Key words: logistics; digital technologies; ergonomics in logistics; Industry 5.0.

1. INTRODUCTION

In relation to the topic in my dissertation, the article focuses not only on the use of digital technologies in the context of automation and productivity improvement but also in the context of improving working conditions in the field of ergonomics, since ergonomics also helps to solve the problems of human participation in automated systems or worker satisfaction itself.

The field of ergonomics is affected by digital technologies, for example, when working with loads, which in the long term affects the health of employees. Ergonomics also helps to solve problems of human participation in automated systems or worker satisfaction itself.

Many industries have undergone a major transformation in recent years with the advent of digital technologies. Many processes are being replaced by automation, and concepts such as digitization, artificial intelligence, and the Internet of Things are coming to the fore.

Digital technologies contribute significantly to more efficient production processes. They make it possible to interact with the virtual workplace without physically damaging the equipment or harming the health of the worker, and they make it easier and more pleasant for workers to carry out their work, especially by relieving them of physical labor and working with loads.

Based on the latest knowledge, the use of digital technologies can be identified as one of the most important areas in production optimization. For example, the use of digitalization in production and logistics systems can provide companies with more accurate and reliable data on the progress of the production or logistics process.

Businesses are thus able to set up production processes more efficiently, reduce costs, increase productivity, or accelerate innovation in production. The latest digital technologies are also radically transforming the industrial production environment, and it can be assumed that, for example, digitization technology will gradually be seen as a necessity for all businesses that want to continue to operate sustainably and remain competitive.

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2. CASE STUDY

The case study deals with the implementation of technology in the company's reverse center, which is located in Sereď. The center's parent company was established in the USA in 1994 and, in its early days, was primarily engaged in the sale of books, but over time, the range of products has expanded to include almost all types of goods. The company operates on the global market, and in Europe, it has branches in Germany, Italy, and France. Most of them are used for the distribution of goods.

However, the branch, which was established in 2017 in Seredi, serves as a specialized reverse center where returned goods from all over Europe arrive. All returned items here are checked and then returned to the salesperson based on their condition.

The term reverse logistics can be used to describe all operations and activities that are associated with the reuse of products and materials. It is the process of planning, controlling, and creating a cost-effective flow of raw materials in order to reuse information.

1.1 Improving safety in logistics through digital technologies

Implementing technology in the workplace is an important part of any company today. They bring many advantages, both economically and ergonomically, when they help, in many cases, increase the safety of workers. Examples of such technologies in logistics are, for example, automatic sorting stations, crate lifters, or robotic arms.

The company, which operates a wobble center in Sereď, has created its own European innovation lab based in northern Italy to improve the worker experience through the development of advanced digital technologies that support safer ways of working.

Fig. 1 Special reversal center in Sereď (Atp Journal, 2022)

The technologies developed in this lab build on previous successful implementations of robotic units around the world, totaling more than 350,000. An example is the quarter-sided yellow shelf towers that help workers move stock items, significantly reducing the distance employees need to travel. Another example is robotic pallet movers, which eliminate the need for workers to handle heavy loads or perform duplicate tasks.

The lab's primary focus is on testing and developing future technologies that will improve workplace safety and also bring increased ergonomic comfort to workers. In the following section, we will mention some of the technologies that the company is successfully applying in its logistics centers in Europe, namely:

- **Item sorters:** this is a fully automated system of sorting items, which greatly reduces the muscle load of the worker, who does not have to manipulate items in crates and tediously search for them.
- **Pallet movers:** are robotic arms that eliminate the need to use forklifts to transport pallets.
- **Crate lifters:** are machines that automatically lift crates and place them on conveyors.
- **AGV trucks:** similar to robotic units, these are robotic support. Automatically guided carts move around the workplace, moving items closer to employees. The benefit is not only the time saved on moving but also the handling of loads, which includes carrying or pushing crates and trolleys.

The trolleys are equipped with sensors and follow predetermined routes. In this case, the risk of injury or collision between the worker and the trolley is reduced or even eliminated.

- **Robotic sorters:** are smaller robotic arms that have eliminated duplicate tasks such as lifting and stacking goods or turning in the company's logistics processes. They also give workers the space to perform better and focus on work tasks that technology can't.

Once digital technology is introduced to the workplace, it is overseen by the company's team of specialists to ensure ongoing safety. In addition to overseeing security during the ramp-up period, this team also provides employees with comprehensive training on how to work with the introduced technology.

Another technology that is often integrated into logistics processes lately is the technology of unmanned aerial vehicles (UAVs), which have a wide range of applications. The way they are used, and their characteristics allow the use of UAV technology in various sectors ranging from transport, armed forces, emergency services, agriculture, manufacturing, the aforementioned logistics, and many other areas.

UAV technology has also been used in logistics processes, for example, in Slovakia, France, and other parts of Europe. In Slovakia, this technology was used for the first time in August 2021, thanks to the cooperation of two companies. A company dedicated to unmanned and autonomous aircraft and a company focused on logistics in the automotive industry.

The company, which is dedicated to autonomous and unmanned technologies, created special control software that made it possible to move with UAV technology in warehouse spaces. The software was tested in a model environment, and the first trials in a real warehouse space took place in September 2021.A company that focuses on logistics was thus able to use the technology in the context of stocking inventory for a client in the automotive industry. Unmanned aerial vehicles (UAVs) are thus providing inventory for approximately one third of the 10,000 m2 facility. The investment is expected to return to the client in approximately 17 months. However, early in the project, one of the benefits for the client of automated inventory was a significant speed-up in the process.

Inventory counts were conducted by staff in the forklift cage prior to the deployment of the UAV technology. This process was thus a lengthy but particularly dangerous activity for employees. In addition to the annual inventory, the company also conducts a sectoral inventory at a monthly frequency. By changing the process using UAV technology, the inventory can be carried out much more safely and with a relatively significant time saving. In addition, such inventories can be carried out during employee breaks, at night, or on weekends.

The first phase of the process is semi-automated; the worker has an application to control the UAV technology, in which he marks the area where he wants to take inventory. The UAV then places the worker in a so-called starting position in front of a specific shelf and starts the inventory process. From this point on, the process is fully automated, using the technology to capture the labels of the goods, which are then compared with existing data in the system.

As the process is not continuous, the use of technology is not calculated to save on manpower per se but rather to speed up the process. In fact, the company plans to use the technology also on areas where vehicles are stored, which are tens of hectares in size, and inventorying by manpower is extremely time-consuming on such an area.

1.2 Digital technologies in logistics

The returns center in Sereď processes approximately one million items per week. Each item contains a specific barcode, which can be used to verify which item it is and who returned it. Subsequently, the items undergo a manual inspection, where their quality and any damage are examined more closely. In the inspection process, the staff use software from the parent company to guide them through the inspection process.

The system asks the worker questions on the display device that focus on the qualitative characteristics of the item. Based on the worker's answers, the system then optimizes further questions relating to the manufacturer of the returned product or item, whether it is a brokered product, or a product manufactured directly by the company, and, finally, whether the particular product has an internal memory that needs to be flushed.

After the condition is assessed, the goods are then placed in colored crates and transported by conveyor belt to the location designated by the system. Based on the barcode on the crate, the system determines the next destination for the item. The color-coded crates are used for categorization and for visual management for the return center staff.

For items that can be put back into circulation and resold, further checks must be made, such as the degree of deterioration, potential marketability, or the condition on the basis of which the price of the item is subsequently determined.

The company implemented a robotic arm from ABB, which is used for palletizing sorted items. Specifically, the IRB 660 robotic arm weighs 250 kg and has a reach distance of 3.15 m. The robotic arm can transfer up to 510 crates per hour. The cabling as well as the air conditioning and other parts of the robotic arm are mounted inside the robot, minimizing the possibility of injury, breakage of wires, and wear and tear.

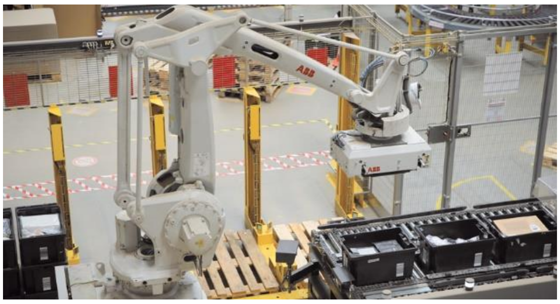

Fig. 2 Robotic arm IRB 660 in reversal center in Sereď (Atp Journal, 2022).

1.3 Industry 5.0 in logistics

The implementation of digital technologies in industry clearly belongs to the realization of the concept of "Industry 5.0, in which the European Commission has listed the three key elements of industry: sustainability, resilience, and human-centeredness.
Industry 5.0's focus on people is also reflected in the European Agency for Safety and Health at Work's 2020 campaign, which focuses on the prevention of work-related musculoskeletal disorders (MSDs). MSDs continue to be one of the most prevalent types of work-related health problems in Europe. Postural risks, exposure to repetitive movements or fatiguing or painful postures, carrying or moving heavy loads—all these very common workplace risk factors can cause MSDs.

Given how prevalent work-related MSDs are, more needs to be done, not least to raise awareness of how they can be prevented. The campaign comprehensively addresses the causes of this persistent problem. It aims to disseminate high-quality information on the subject, promote an integrated approach to managing the problem, and offer practical tools and solutions that can help at the workplace level.

For example, although the possibilities of automation are somewhat limited in reverse logistics due to the need for manual control of individual items, technologies such as robotic arms have recently been implemented in the company to help make workers' jobs easier. Automatic conveyor systems, in turn, help workers move and sort items. Then there are various software solutions that help workers choose the size of the box to pack an item based on its actual dimensions.

3. CONCLUSIONS

Companies aim to implement digital technologies that replace physical work and reduce or eliminate the workload of workers. The human, or worker, is thus replaced only in physical work and the handling of loads, where it adds no value. Conversely, in the actual assessment of the condition of items or other checks, the worker's skills are crucial.

The gradual introduction of digital technologies into the logistics sector can largely prevent musculoskeletal disorders in workers, as they no longer have to handle loads or perform repetitive movements after the introduction of some of these technologies. Load handling has been minimized in some workplaces and eliminated in others after the adaptation of technologies.

The use of modern digital technologies and available tools not only makes work more efficient but also improves the quality of work for employees. Therefore, the necessary direction for companies in the future is to continuously improve ergonomics and reduce the physical burden on workers. In addition, current trends suggest that an increasing share of digitization and automation will make logistics processes not only more agile and reliable but also safer.

ACKNOWLEDGEMENT

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TRANSPORTATION IN ADAPTIVE MANUFACTURING SYSTEM

Abstract

The company has several options for gaining a competitive advantage. In the area of production security, logistic processes dominate. One of the main efficiency criteria is properly and efficiently functioning corporate logistics. If the logistics work correctly, then the production and assembly processes also work reliably; they are only affected by the failures of technology and workers. In the implementation of logistics, this means setting high flexibility and punctuality at reasonable costs. The article aims to introduce different transport implementations of adaptive manufacturing systems.

Key words: Logistics system; Adaptive manufacturing system, Digital model,

1. INTRODUCTION

All new production concepts strive to fulfil one main goal: adaptability, the ability to immediately react to rapid changes in the environment, also referred to as turbulence. Adaptive production systems are currently the pinnacle of scientists' efforts to formulate the contours of the future production environment. Meeting the requirement of adaptability can be approached in several ways, which is why scientists have elaborated, developed and tested a whole group of new production concepts, such as reconfigurable production systems, competence islands, multi-agent management systems, etc. [1].In the adaptive production system, the transport system is supported by mobile units with access to any production means.

Logistics itself is an important area of any business. The efficiency with which logistics works in companies often reflects the company's efficiency. In companies that do not fully manage their logistics processes, there is an increase in the production lead time. This increase has an impact on the competitiveness of the company and its finances. The automotive industry is directly dependent on good logistics [2].

The primary task of logistics in a manufacturing company is to ensure the physical delivery of the necessary material inputs (materials, semi-finished products, auxiliary materials, etc.) for the implementation of the production process, ensuring the material flow in the production process itself and the delivery of finished products (products) to customers. Logistics must guarantee the process of delivering the necessary goods in terms of type, quantity and quality to the right place, at the right time and the lowest costs [3].

Logistics in the automotive industry has two areas of operation. The first is the provision of logistics processes within the assembly company itself (production logistics, distribution logistics). The second area is the provision of logistics in pre-assembly subcontracting operations (supply logistics), i.e. within the production of components and transport to the assembly site using the Just-in-Time (JiT) or Just-in-Sequence (JIS).

2. THEORETICAL BACKGROUND

2.1 Adaptive manufacturing system

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A production system that focuses on the ability to respond to internal and external changes immediately. The main criteria are autonomy, self-organisation and reconfigurability. Adaptability is achieved by the internal logic of the production system, technological conveniences, and people's abilities [4].

Mathematical evaluation of the adaptive manufacturing system [4].

The first is a function (1), which compares the number of products with the number of lines. In the case of an adaptive production system, it should be true that the number of products is greater than the number of production lines; respectively, individual products do not have a precise determination of each means of production on which they will be processed.

$$Number\_of\_products \geq Number\_of\_Lines \tag{1}$$

Another function (2) refers to the number of variants of one product. Suppose the number of variants of one product is greater than the number of operations. In that case, the variability does not affect the number of operations in the production process. Thus, within one function, it is possible to process more steps and thus achieve different product variants. If equality occurs in this case, we would not be able to speak of an adaptive production system because there would have to be a different production plan for each variant.

$$Number\_of\_Variants \geq Number\_of\_Operations \tag{2}$$

The last function (3) that affects the production system is the number of operations and the number of means of production. If the number of operations in the production process is more than the number of means of production, more operations can be processed on one means of production. Thus, the adaptability of the production process is achieved.

$$Number\_of\_Operation \geq Number\_of\_Machine\_per\_Operation \tag{3}$$

2.2 Logistic requirements in adaptive manufacturing system

Manufacturing and logistics are closely related and significantly impact one another. Maintaining production and information flows into and throughout the organisation, managing the procurement of raw materials, freight transport and storage of materials, production and dispatch of finished products, planning and carrying out standard logistics procedures to satisfy the needs of manufacturing operations and customer demands [5]. These actions and tasks fall under effective logistics management to reach sustained profit levels and cost-effective order fulfilment. But as logistics and industrial manufacturing become more sophisticated, businesses need help to overcome several difficulties. Due to companies' ongoing evolution and search for innovative production and logistics management methods, conventional logistics tactics have become obsolete over time.

Logistics requirements in an adaptive manufacturing system:
- selection of products,
- selection of means of production,
- path selection,
- effective management strategy.

Transport zone and is responsible for transporting the product from the entrance to the necessary technological processes by the best possible route. The means of transport must communicate with the agent of the product to which means of production it must reach, based on which the means of transportation will evaluate the possible paths.

The adaptability of the transport zone lies in the decision-making conditions of which means of production will take which product to its destination.

As part of active adaptability, self-organisation, reconfiguration, autonomy, self-optimization and self-learning must occur in logistics. The appropriate configuration of the internal logistics system determines, on the one hand, the performance characteristics of the own logistics system. Still, on the other hand, it also determines the performance of the entire production system.

2.3. Technologies requirements for logistics in adaptive manufacturing system

To ensure the adaptation of the entire logistics system, Adaptive logistics systems will use a wide range of progressive technologies. Individual elements of the logistics system will be equipped with small, powerful computers, so-called embedded intelligence, which will expand their functionality and autonomy. The ability to communicate with each other will be supported by a new generation of wireless sensor networks, using intelligent information infrastructure, Internet of Things technologies and cloud services [6].

Among the new elements of adaptive logistics can be included: a holonic system of autonomous management of logistics in real-time, the modular structure supporting reconfigurability (plug and produce), mechatronic systems and embedded intelligence, sensors and actuators of devices (systems for internal actions), sensors for the logistics system environment (systems for external activities), simulation-emulation systems for decision support standardised interfaces (mechanical, electrical, electronic, software, network, ...), learning system (before the action, in action, after the action), knowledge base (Knowledge base) and best practices based [7].

The application of the Internet of Things in the field of logistics will also play an important role in the future. This condition will have to be met because, with adaptive logistics, there is a need for very fast, mutual communication of individual logistic elements. The Internet of Things is experiencing dynamic development also in terms of logistics, where the problem of emergence will occur in the future. The developers are trying to solve this using Internet of Things technology and agent management of internal logistics [8].

3. CASE STUDY

Designing the logistical systems is a crucial component of creating the production system. Therefore, it is important to consider your options and choose the best logistics plan. Technologies employed in the preproduction stage of planning and the control of logistic processes, in addition to those directly related to the execution of various logistic activities, are crucial enablers for the high efficiency of the logistic processes.

In the course of the digitalisation of production and logistics, as well as the equipping of logistics objects with sensors (Internet of Things), an intelligent factory is created, enabling a new internal process logic. Flexibility and the ability of logistics systems to adapt and adapt is a basic requirements for logistics 4.0. Modular material flow systems can achieve this ability to adjust and adapt. The modularisation of logistics systems thus forms the basis for a high degree of flexibility and adaptability. Decentralised management concepts in this context have certain advantages over conventional, hierarchical management architectures.

The main difference between logistics for an adaptive production system and a traditional production system is that the products that are produced do not have a defined production path, and each variant has a specific work plan. It is, therefore, necessary to ensure flexible options and availability for each means of production. Of the production system, two options for setting up the logistics flow are demonstrated.

Experimental verification is taking place with the company XYZ, which manufactures a part of car dashboards. The company has several customers that assemble cars, which are also directly subject to the end customer and their requirements. At the same time, the end customer’s requirements are reflected in the requirements for the XYZ company. Within its production, the company has several different customers. Product variability is, therefore, high. The volume of production is variable, but due to the trend of product customisation, the sizes of production batches are constantly decreasing. The company uses modern technologies such as sensors, robots, AGVs and ICT in production.

Based on these characteristics of the production company and the fulfilled mathematical definition of production characteristics, I consider the company suitable for experimental verification in creating a digital model of an adaptive production system.

3.1 AGV and AMR system in adaptive manufacturing system

Until recently, automated guided vehicles (AGVs) were the only option for automating internal logistics. They have become a must-have in large, fixed installations despite their high initial costs and more extended payback period. The limitation is fixed routes and the impossibility of overcoming an obstacle in the path, despite the fact that the device can detect it. Downtime can occur here, which can cause an increase in costs for the company. Compared to picking goods only by operators and manually driven vehicles, this solution is much more suitable for optimising processes and increasing picking speed.

Autonomous mobile robots (AMR) are navigated through maps that are created directly by the robot walking around the campus. AMR uses data from sensors and cameras to create maps and distributes the completed map to other devices. Thanks to this, they can effectively change their route in the event of an obstacle in real-time and thus avoid downtime during material picking. Thanks to their high flexibility and agility, AMRs are suitable for modern production environments, which can be highly dynamic and require equipment that can quickly adapt to changes if you optimise warehouse processes in your company and strive for maximum efficiency.

3.2 Verification of logistics approaches using a digital model.

In this sub-chapter, the creation of an adaptive production system model will be presented, and two logistics system approaches (AGV vs AMR) will be evaluated on a digital model. The software used is Tecnomatix Plant Simulation version 16.1.

In the first step, collecting and structuring data into a suitable form is necessary. Since we are talking about an adaptive flow system, the links between the data are many to many. In the case of such data, it is necessary to use nested tables, as shown in Figure 1.

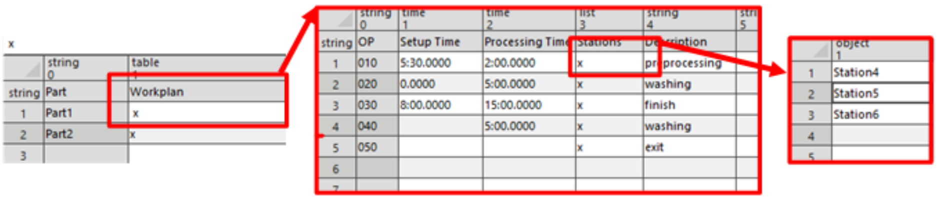

Fig. 1 Nested tables: Working plan

In the next step, it is necessary to implement product selection strategies, initial strategies, etc., into the model. Individual strategies are shown in table 1. Strategy selection and strategy evaluation are described in more detail in Burganova N. 2022.

Tab. 1 Logistics strategies

Strategy	Final selection
Sorting strategy	Hierarchically: DueDate then Customer then Price then Batch Size then FIFO
Exit strategy	The free resource, then minimum total load, then shortest processing time + shortest retyping time.
Pick up strategy	DueDate

After implementing the strategy, two digital models were created, one using a logistics system using AGV and the other using AMR. Figure 2 shows those models. The models are only illustrative due to the company's sensitive data.

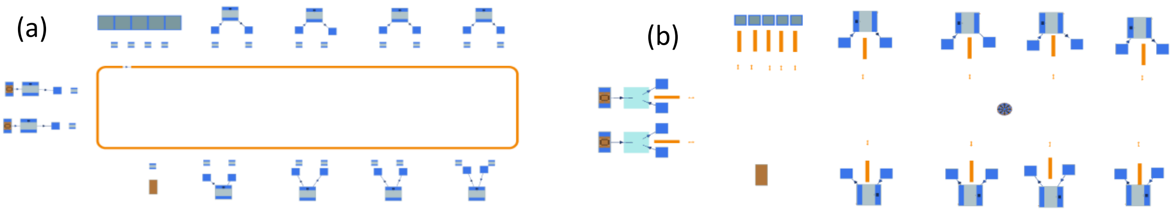

Fig. 2 (a) AGV system; (b) AMR system

Figure 3 shows a comparison of two logistics methods (AGV, AMR); three different outputs were compared, namely the number of products that left the production, the percentage of transport time and the average lifetime in production. It is clear from the results that the AMR system is more advantageous to use in adaptive production systems. This is because the AGV systems that are used so often need to manage the necessary flexibility of the system.

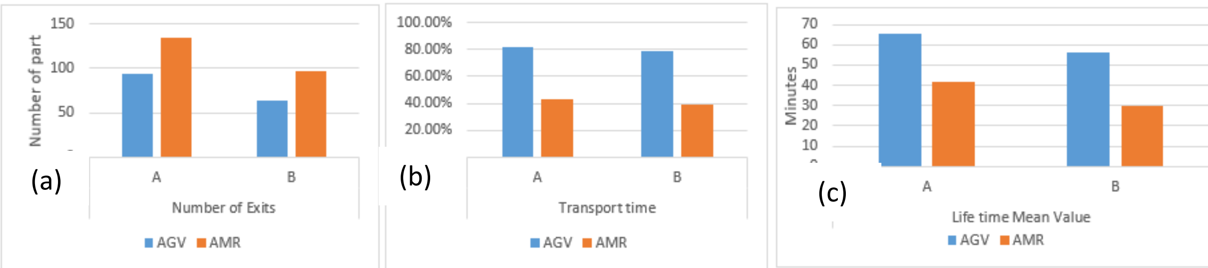

Fig. 3 Results: (a) Number of exits; (b) Transport time; (c) Lifetime mean value.

4. CONCLUSION

The article presents an adaptive production system with the most used possibilities of the logistics system. As part of the Case study, a digital model of a specific adaptive production system is created. An adaptive production system must, first of all, fulfil the mathematical functions required. In the digital model of the adaptive manufacturing system, there are special requirements for data structuring about the relationships between data. Another critical step is implementing strategies that support system adaptability into the logistics system. And finally, it is necessary to choose logistic methods, which was the article's primary goal. The simulation results showed clearly in favour of the AMR system.

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PERCEPTION OF NEW TECHNOLOGIES WITH REGARD TO DIFFERENT GENERATIONS OF EMPLOYEES IN INDUSTRIAL ENTERPRISES IN SLOVAKIA

Abstract

The implementation of new technologies in industrial enterprises has an impact not only on the performance of organizations, productivity and economic results, but also on the working environment, jobs and employees of organizations. In the article, the research results are presented, focused on how different generations of employees perceive the introduction of new technologies in organizations and the threat to their jobs. The article also presents the results of how employers provide the development of the necessary digital skills of employees in industrial enterprises in Slovakia.

Key words: employees, generations, industrial enterprises, technologies

1. INTRODUCTION AND LITERATURE REVIEW

Enterprises aim to increase profits and reduce costs through the introduction of digital technologies. At the centre of these changes is the effort to attach new customers by adjusting the goods, services, and systems according to their needs. Insufficient qualification of employees in the areas of new technologies is the biggest challenge for enterprises in the area of adapting these technologies [4]. In addition to the level of qualification, the willingness of employees to accept new technologies can also be influenced by their previous experiences with technology usage, which can vary due to generational differences among employees.

Roth-Cohen [2022] states in her publication that generations include individuals born around the same time who were influenced by the same technologies, media, or events. Currently, the society consists of 4 generations. The first generation called the baby boomers (Generation BB) were born between 1946 and 1960. Regarding technology, baby boomers are usually described as people who have very little interest in the use of information and media technologies, although their rate of receiving information from these technologies is increasing. Nevertheless, they still fall behind the younger generations [8]. Due to their extensive experience and established work habits and procedures, employees from the baby boomer generation may exhibit resistance to change and feel insecure about the implementation of new technologies. As a result, they may perceive the introduction of new technologies as a threat. [7]. Generation X consists of people born between 1961 and 1980. Generation X is referred to as the first technological generation. Throughout the course of this generation's lives, technologies have gradually emerged and gained importance, particularly in terms of their utilization and the need to adapt to them [9]. This generation is referred to in the literature as "digital immigrants". Generation X, unlike subsequent generations, did not grow up surrounded by IT technologies, so they had to learn digital skills at the cost of considerable time and effort [1]. Generation Y consists of young people who were born between 1981 and 1995. Generation Y does not need to learn what these technologies are for, they know how to use them intuitively and feel comfortable in a digital society. This generation has access to a huge amount of information [9]. Internet communication has become

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a natural part of their life because this generation uses modern means of communication on a daily basis. The boom in modern technologies, which is related to smartphones and the rise of social networks, has moved the possibilities of using digital technologies and communication to a higher level [1]. Representatives of Generation Z are people born between 1996 and 2010. Generation Z is quite different from the previous generations X, Y or baby boomers. These are young people who are the most technically advanced generation so far. This generation has practically connected with modern technologies, and representatives of this generation are constantly "glued" to screens of all kinds [8]. In general, Generation Z expects to have access to modern tools and technology in their work sphere. They are usually very skilled in using mobile devices, applications and social media [10].

2. METHODOLOGY

The introduction of new technologies is an unstoppable trend, the speed of which is constantly accelerating. In Slovakia, several studies focused on the implementation of technologies and their impact on employees [e.g. 4, 3, 5]. However, the comparison of Slovakia with 63 countries in the world in terms of digital competitiveness does not look flattering [4]. In the survey, the results of which are presented in this article, we focused on how the enterprises employees perceive the implementation of new technologies and the threat to their jobs due to their implementation. For the purposes of the research, a questionnaire aimed at collecting quantitative data was created on the basis of two qualitative pre-researches. From the collected answers, only the answers of respondents employed in industrial enterprises were selected for the purpose of analysis. Descriptive statistics tools were used to evaluate the results.

3. RESULTS AND DISCUSSION

A total of 344 responses from respondents exclusively from industrial enterprises were analysed. The research sample consisted of 213 men and 131 women, as we can see in figure 1.

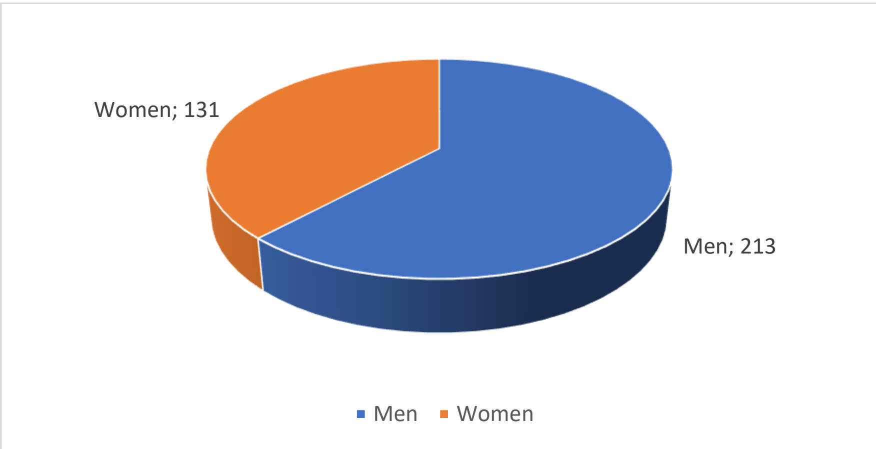

Fig.1 Gender of respondents [own development]

We also divided the respondents according to the size of the industrial enterprises in which they are employed. We divided the enterprises according to the number of employees into 4 categories, which can be seen in table 1.

Tab.1 Size of industrial enterprises represented in the research [own processsing]

Size of enterprise	Men	Men [%]	Women	Women [%]	Summary	Summary [%]
1 - 9	11	5,16 %	5	3,82 %	16	4,65 %
10 - 49	17	7,90 %	8	6,11 %	25	7,26 %
50 - 249	43	20,19 %	21	16,03 %	64	18,61 %
250 and more	142	66,66%	97	74,04 %	239	69,48 %
Summary	213	100 %	131	100 %	344	100 %

As can be seen in table 1, employees of large enterprises had the largest representation. In the research, we divided respondents according to their age into 4 generational groups. The absolute and relative representation of respondents in the research can be seen in table 2.

Tab.2 Representation of various generations in the research [own development]

Generation	**Absolute frequency**	**Relative frequency [%]**
Generation BB (1946-1960)	2	0,61 %
Generation X (1961-1980)	105	30,50 %
Generation Y (1981-1995)	190	55, 23 %
Generation Z (1996-2010)	47	13,66 %
Summary	344	100 %

The study examined how employees perceive the implementation of new technologies. We also examined this perception based on the generational diversity of employees. One part of the survey focused on examining employees' perception of threat resulting from the implementation of new technologies.

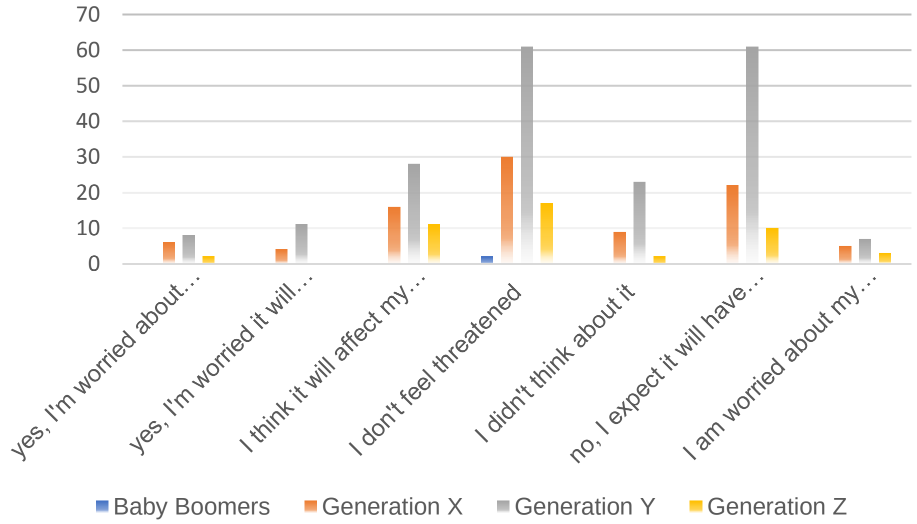

Fig.1 Perception of technology as a threat to employees [own development]

The analysed results show that among the employees of industrial enterprises, a portion of employees experience feelings of threat in relation to new technologies. They express concerns about potential job insecurity and are open to acknowledging these concerns. Generations X and Y, who represent the largest number of employees within the entire population, feel the least threatened. On the other hand, generation Y tends to have a positive perception of technologies and their impact on jobs. They possess an intuitive understanding of new technologies, which enables them to adapt to them more easily and effectively incorporate them into their work processes. Other concerns related to work, specifically the economic consequences of COVID-19, are distributed equally among the different generations. Certain deviations in perception are primarily caused by the fact that every person is different and there are always exceptions even within the same generations. As confirmed by the results of previous research, a significant influence on the acceptance of new technologies is also influenced by how the employees themselves evaluate the effectiveness of technology in handling work tasks [6].

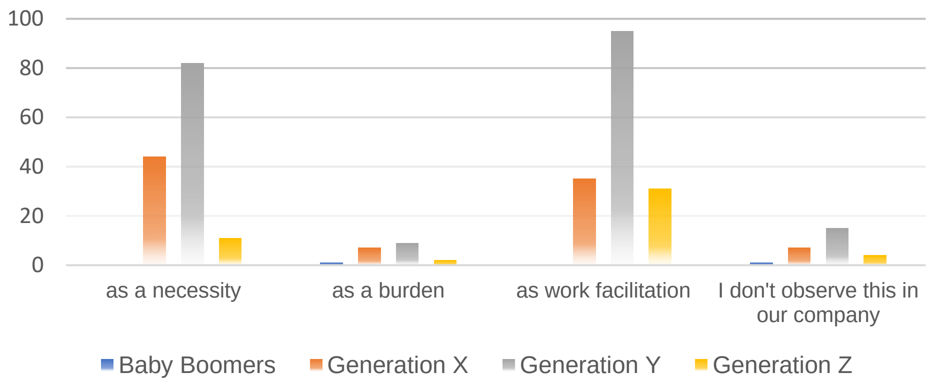

Fig.2 General perception of the implementation of new technologies [own development]

Another aspect covered in the survey was the perception of employees regarding the implementation of new technologies within industrial enterprises. We also analysed this perception from the point of view of generations. As we can see on fig 3, the implementation of new technologies as a necessity perceive generation X, Y, Z. The baby boomer generation perceives new technologies rather as a burden. Especially the younger generation of employees perceive new technologies as work facilitation. This is primarily due to the fact that these generations are more adept at working with new technologies. As confirmed by the results of other research, faster access to information is beneficial for employees in various ways. Moreover, sharing information about the happenings within the organization with employees creates a certain bond that is crucial for employee engagement. Technologies, among other things, bring flexibility to employees, reduce duplication (such as repetitive tasks), and increase work pace. All these factors positively contribute to employee engagement [2].

In view of the recent pandemic, we also examined how employers in Slovak industrial enterprises ensured the development of digital skills.

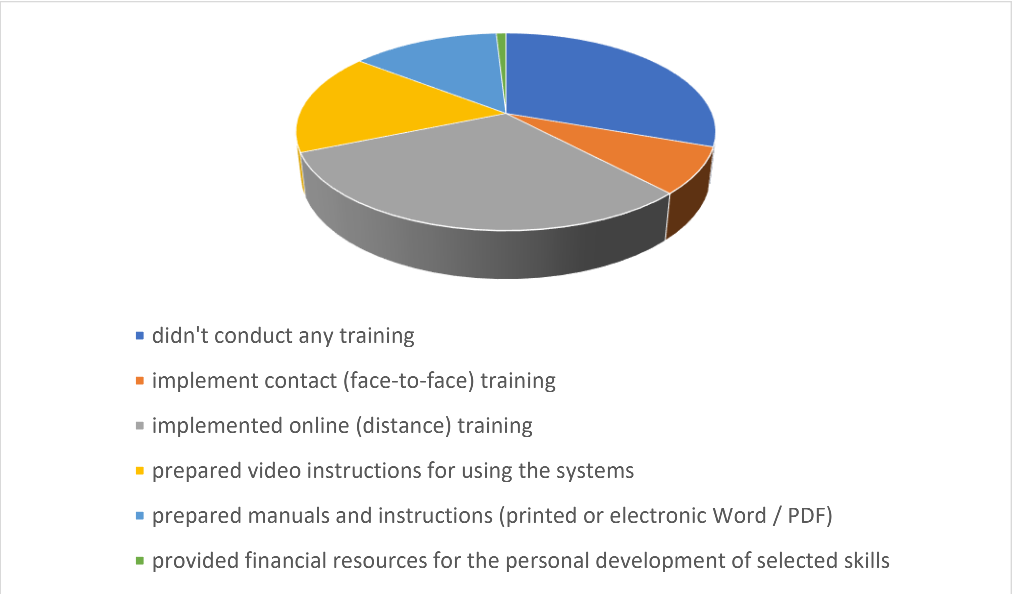

Fig.3 Development of digital skills by employers [own development]

The figure above illustrates that the development of digital skills was not categorized according to generations. Figure 4 reveals that the predominant approach employed by employers to enhance employees' digital skills is through the implementation of online (distance) training. It represents 31% of all activities focused on developing digital skills. Preparing video instructions or manuals as well as printed instructions accounts for 31% of the implemented activities. Contact training sessions were utilized to a lesser extent, and some employers provided financial resources for the personal development of selected employee skills. As we can see from the graph, there are also 30% of employers who did not conduct any employee training.

Considering that the greatest challenge for enterprises in the adaptation of these technologies is the insufficient qualification of employees in the field of new technologies, investing in digital education becomes one of the major challenges for enterprises [4].

4. CONCLUSION

The paper presents the results of how employees of industrial enterprises perceive the introduction of new technologies at the workplace, which is an important part of their implementation. As can be seen from the results of the presented research, the perception of new technologies varies among all generations. Although technologies bring limitations by blurring the boundaries between personal and professional life, they also bring many advantages. An important aspect of how new technologies are utilized is their acceptance by employees. As mentioned earlier, employees' education plays a significant role in shaping their initial perspective. The perception of how employees perceive the usefulness of implemented technologies is also important. It is crucial for employees of enterprises to be informed about upcoming changes as fear of the unknown generates the most concern. Sharing information is necessary not only for the acceptance of new technologies but also for their smooth functioning, as it fosters a sense of trust and belonging.

ACKNOWLEDGEMENTS

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GAME-BASED LEARNING: AN INNOVATIVE APPROACH TO INDUSTRIAL ENGINEERING EDUCATION

Abstract

Nowadays, it is difficult to attract the attention of students during education. One of the ways to achieve this is the use of games in the educational process. Game-bassed learning is increasingly used in foreign colleges and universities because it brings several advantages over traditional teaching. Interactive activities associated with the game can capture the attention of students and involve them in solving problems and finding alternative solutions. Students thus gain practical experience and, through a playful form, learn managerial knowledge and skills in the field of production systems, logistics and quality. In industrial engineering, there is a lot of room for the application of teaching through games. The aim of this article is to indicate how higher education meets the requirements of industrial practice according to the principles of Industry 4.0. This can be achieved by implementing own training game as an innovative tool in the educational process. In this way, the study of the field of industrial engineering and management will be improved. The training game presented in the article is designed to provide automated data collection to a cloud database. The gained data can then be quantitatively evaluated and used to create time analyses of production processes and to apply lean principles in the analysis of these processes.

Key words: games learning, education, support

1. INTRODUCTION

Nowadays, traditional methods aren´t the focus of students in the educational process. With the rapid development in knowledge and applications of technological progress in industrial practice, it is necessary to look for new ways to change this situation. One proven solution is the incorporation of Game-Based Learning (GBL) into the educational process. The need to motivate students to stay engaged for long periods of learning is often used in a literature as the main and most important argument for using games in educational contexts [1]. GBL is an educational approach that integrates games and play elements into the learning process to increase engagement, motivation and learning outcomes. This approach can be implemented using digital and non-digital games that are either specifically designed for teaching purposes or adapted for educational contexts [2]. The use of games in education is often described in the context of their potential to enhance learning by directly engaging users in play [3]. Therefore, it is important that users feel immersed and involved in the game. GBL games have a strong impact on learner motivation because they combine interactivity, challenge, competition, feedback and fascinating stories [4]. Games further encourage students to take risks and try different ways of learning and thinking with fewer consequences for failure [5]. Integrating GBL into the learning process can have a positive impact on learning outcomes as well as the development of various skills such as critical thinking, problem solving, collaboration, and creativity. In this way, students are provided with a structured and fun environment in which they can actively pursue and learn.

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The most significant impacts of the use of new technologies are expected to be felt primarily in the industrial sector. Automation, digitization and robotics are likely to reduce the demand for labor in industrial production, leading to a reduction in the number of people employed in the sector. However, the quality of the workforce is also changing thanks to new technologies. Not only are old jobs and occupations being transformed or abolished, but new opportunities are also being created as we can see in the table below [6].

Tab. 1 Predicted workforce changes in next 5 years [based on 6].

EMERGING WORK POSITIONS IN NEXT 5 YEARS	**DECLINING WORK POSITIONS IN NEXT 5 YEARS**
Data analysts and scientists	Assembly and factory workers
AI and machine learning specialists	Data entry clerks
Process automation specialists	Client information and customer service workers
Software and applications developers and analysts	Accountants and auditors
Innovation professionals	Accounting, bookkeeping and payroll clerks
Service and solutions designers	Administrative and executive secretaries
Product managers	Transportation attendants and conductors
Industrial and production engineers	Material-recording and stock-keeping clerks
Supply chain and logistics specials	General and operations managers
	Business services and administration managers

These new jobs will have different staffing requirements compared to the current ones. This means that new or different knowledge, skills and abilities will be needed more than ever before. This trend poses significant challenges for education at all levels. There is likely to be a strong demand in the labour market for people with appropriate competences in software development, information technology and information communication, as the use of software, connectivity and analytics is expected to increase. In addition, other skills and competences (such as flexibility, creativity, problem-solving, decision-making, etc.) will be necessary to cope with the challenges of the labour market in the coming decades. These changes are turning the world of work upside down and could cause serious problems. Therefore, it is very important to identify new skills and competences that will be relevant in the future [7].

2. METHODOLOGY

The aim of the research was, based on the current needs of industrial practice, to adapt the system and tools used to educate the taught generation (millennials) by introducing creative techniques and tools into the educational process, through the application of Games learning and the following partial objectives:

- Implementation of activities supporting the connection of higher education with the requirements of industrial practice in accordance with the principles of Industry 4.0 / 5.0, as well as the creation and development of innovative tools for the educational process and thus improving the quality of the teaching process. This method can improve the quality of education and practical readiness of students to the level of foreign colleges and universities.
- Collection and evaluation of data and preparation of case studies for the enrichment of teaching as well as for their statistical evaluation and subsequent dissemination of results in the form of scientific publications in professional and scientific forums.
- Increase users' skills and experience towards the ability to think innovatively and comprehensively for future graduates, with an emphasis on more effective problem solving in the areas of time studies, identifying and eliminating waste, creating and streamlining layouts, in-plant supply, manufacturing and assembly, production management, Lean Production, process improvement, and innovation, and more - they will gain the ability to solve a problem from its technical, human, informational, and financial aspects.
- Creation of a user platform for physical layout modelling of a simple production/assembly layout in order to identify the capabilities and limitations of a given static layout.
- Find a suitable way of defining and designing the dynamic layout of a production/assembly unit with virtually no constraints.

The output is a physically realized training game for educational purposes with defined static layout, described in detail in the following chapter.

3. RESULTS

Based on the content of study programs focusing on industrial engineering and Industry 4.0 as well as on the challenges of application practice, the diversity of necessary knowledge and skills that graduates must acquire, it is necessary to enrich the teaching process with the use of training games and various forms of Games learning, or experiential learning. In the field of industrial engineering, as well as in the field of management, many different forms, methods, techniques, and games can be used to approach (or at least model, and simulate) real company conditions and thus complement the theoretical knowledge acquired during classical contact teaching during lectures. It is relatively easy to find training games for individual areas and issues, but it is more difficult to find a platform that offers a combination of knowledge from several areas or offers universal use. Universal games usually have the disadvantage that they do not address in detail the individual areas of study, but focus on the system as a whole. Subject-specific games, on the other hand, do not address the systemic impact, but only address the specific area of knowledge use/application. It is this situation that inspired us to think about a solution that would be tailor-made from multiple perspectives. We had purchased a TractorMotive® game some time ago, which further inspired us in that it did not come with a manual; the authors had deliberately designed this management game so that each user would create their conditions and their manual adapted to what they wanted to use the game for. This gave rise to the idea of creating a universal training game for the field of industrial production/assembly unit management that would cover all areas of interest within the studio - starting with production management (time studies, in-house supply, micro layout creation, visual management), optimization of production/assembly processes (Lean methods and techniques, quality management and creation of production standards) as well as the collection and processing of data captured directly within the model game and the subsequent possibility of creating a digital twin (simulation model of the production/assembly unit). [8]

3.1 Static Layout Training Game

The game consists of 4 separate workplaces, which are separated by a divider and are interconnected by devices for transporting semi-finished products (work in progress), implemented in the form of drawers - see Fig. 1 Design of the spatial layout of the workplaces of the model simulation training game. The position of the drawers is crucial in terms of workplace supply, as shifts to the extreme positions represent a signal for the pulling Kanban system within the workplace supply. Each drawer in its operation uses an intelligent position sensor in the form of a push button, which is installed on the dividing wall between the workstations.

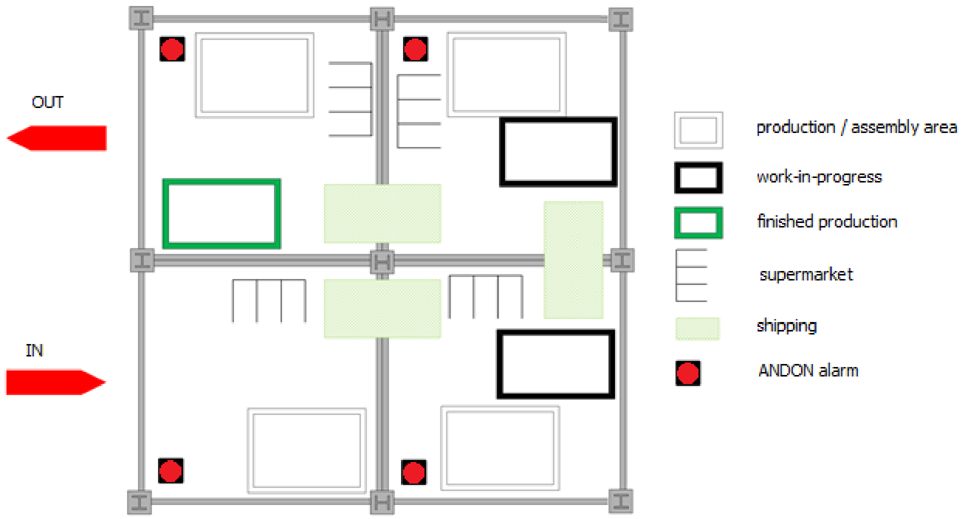

Fig. 1 Design of the static layout training game

In addition, each workstation is equipped with a red signalling button as an Andon signalling, i.e. light-signalling reporting of a fault or any inconsistent condition detected at the workstation. All the buttons are interfaced with the operation control unit, which are 2 pieces of Arduino Industrial type microcontrollers, capturing data – time instants of drawer movement as well as press/release of the Andon signalling. The push buttons send 1/0 data, which the controlling microprocessor sends via the WiFi module on the Arduino Industrial to the web database (Fig. 2. Collected structured data registering in phpMyAdmin platform). The captured numerical series form data packages – the basis for time studies of the production process (basis for calculating tact time, cycle time, operational times at individual workstations) and further for process optimization (basis for Value Stream Mapping – VA/NVA times, etc.). [8]

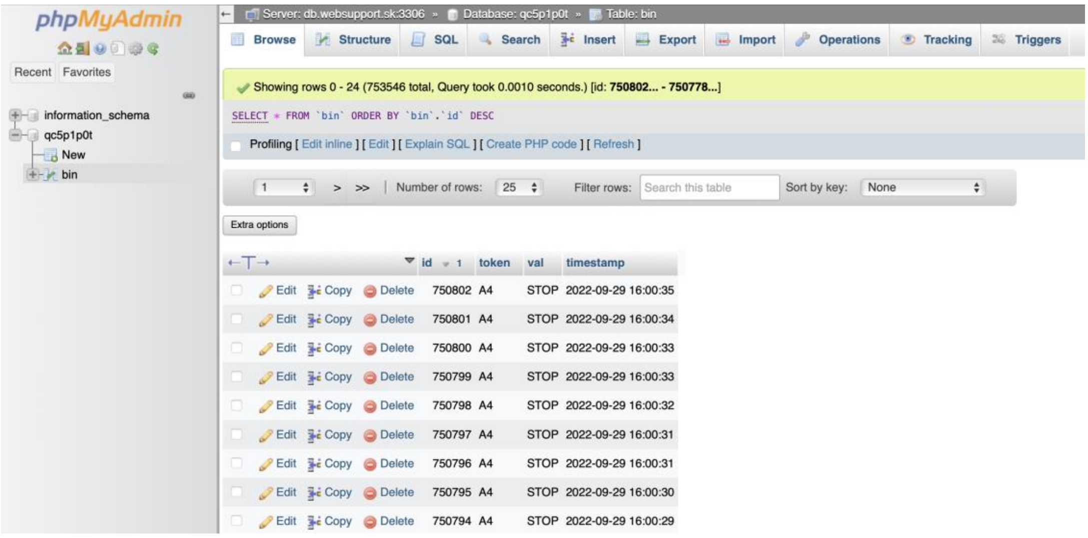

Fig. 2 Collected structured data registering in phpMyAdmin platform

The principle of the training game is to create the conditions of a model industrial production unit, in which the participants learn the principles of operation, management, and supply of the production/assembly unit, in addition, they have the opportunity to partially change the layout of the workplaces due to the elimination of sources of waste, to create new visual management, or the corresponding standards at the workplaces. The basis of game learning and experiential learning is the principle "I hear and I forget, I see and I remember, I do and I understand [9]." - what they try will stay with them and they will see every success achieved in process improvement as their success.

The game links theoretical knowledge in the areas of production management, logistics, production quality management, process management, process optimization, and elimination of sources of waste and helps participants to transfer the knowledge from these areas into a practical application platform – skills that every manager needs to have. In addition to the possibility of using the game separately within the courses for purposeful acquisition, the retraining of knowledge also creates a space for the purposeful integration of practical knowledge and skills, for process integration of interrelated functional areas of industrial production management.
Benefits and resulting competencies gained from the use of Games Learning in the teaching process:
gain an overview of the manufacturing/assembly process of a product, which consists of multiple operations spread over 4 workstations,
to understand the importance and application of the push Kanban system in the inter-operational supply process,

- gain the ability to create standards and work instructions,
- they will practice the work with sorting and processing of raw time data captured by the functional electronics of the training game - they will practice the procedure of calculating operational times, downtimes (or useless/non-value-adding times), cycle times, they will also be able to prepare the basis for the value analysis (VSM), on the basis of which it will be possible to carry out the leaning of processes,
- recognize and learn the importance of visual management and change the micro layout of workstations as required. [8]

Limitations of the created training game:

- layout changes are not possible and the number of workplaces is limited,
- the pull Kanban system is tied to batch delivery via fixed drawers tied to fixed workstation boundaries (due to the way push-buttons capture data),
- layout balancing and optimization is severely limited due to the above factors.

4. CONCLUSIONS

A game-based learning approach, including the use of serious games, is a powerfuldriver to motivate students rather than just providing them with information .Game learning helps [based on 10, 11]:

- Helps problem-solving,
- Encourages critical thinking,
- Increases student engagement and motivation,
- Introduces situational learning,
- Addresses special education needs.

A significant milestone in removing the limitations of the static training game is the design of a dynamic training game layout, which is a sort of upgrade of the static version, but without the physical limitations. The principle of operation remains unchanged, except that the way of passing batches between workstations will change, allowing the removal of fixed barriers by rotating double stacks, which however will no longer need contact push buttons to capture time data, but will only be touch-based based on the position of the rotating stack (always picking up a 180° movement). The new design (see Fig. 3 Final version of the training game with dynamic layout) also allows for other sensor wiring and a different way of communication, e.g. based on Low Range Low Frequency sensors that can communicate with the Arduino microprocessor. In addition to the possibility of plugging in any number of workstations, based on any spatial layout, this way of dynamic layout also gives absolute freedom in leaning and optimization.

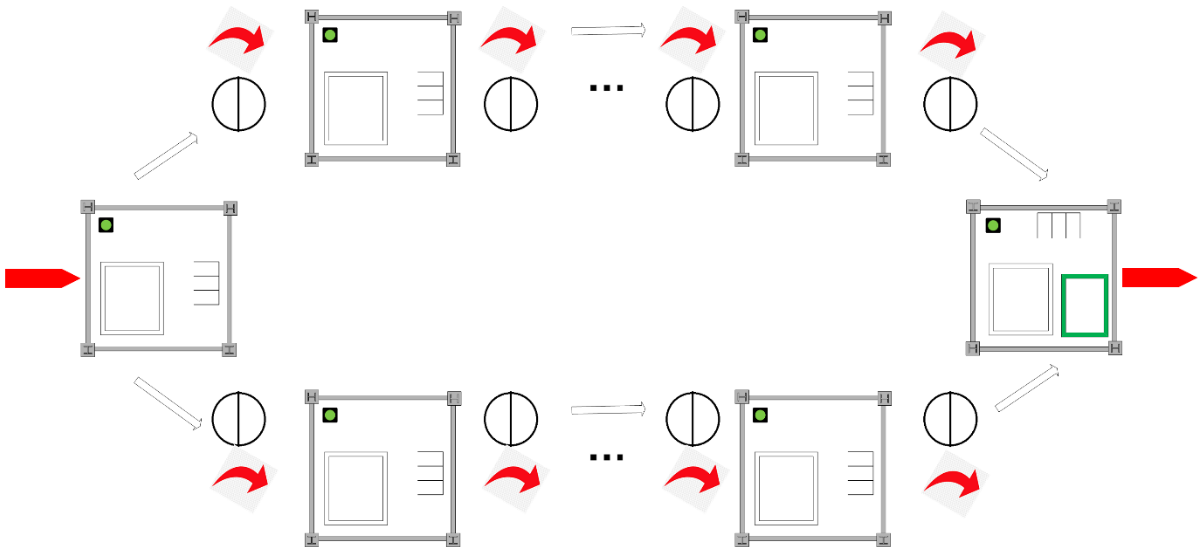

Fig. 3 Final version of the training game with dynamic layout (own processing 2023)

Another important step for the advancement in the field of game learning is the digitalization of all possible training game platforms and the creation of a virtual (digital, simulated) environment within which optimization processes can be carried out without financial losses and with an unlimited number of attempts. A digital factory, or in a smaller case a digital twin of an industrial production/assembly unit, enables optimization activities/processes in a software-simulation environment. The disadvantages are the labor intensity of creating and operating the digital twin and often the low level of human resources to imagine changes in real conditions. It is for this reason that we believe that the linking of physical simulation and virtual simulation models represents an ideal combination in which the theoretical knowledge, practical experience, and critical thinking of creative staff (students, graduates, participants) can be applied. [8]

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PRODUCTION PROCESS SIMULATION COOPERATION WITH KEPServerEX IN TestBED 4.0

Abstract

The topic of this bachelor's thesis is the processing of simulation models, the method of their creation, as well as the evaluation of the possibilities of cooperation in the TestBed 4.0 laboratory. With the help of the Tecnomatix PlantSimulation program from Siemens, a visualization of the production line and a description of the individual steps of its creation was designed. KEPserverEX was used for the connection and communication between the Tecnomatix PlantSimulation program and the PLC, thanks to which it was possible to fulfill the goal of this work and to connect the CNC device that communicates and cooperates with the PlantSimualtion program.

Keywords: TestBed 4.0, Tecnomatix Plant Simulation, PLC, KEPserverEX

1. INTRODUCTION

Process simulation is already an inseparable part of the industry and the efficiency of production processes. Digitization and automation, which is part of Industry 4.0, is the bearer of changes entering the current industry, at all levels of management of business processes and services.

Create well-structured, 3D hierarchical models of manufacturing facilities, lines, and operations for fast and efficient modeling of discrete and continuous manufacturing processes using powerful object-oriented architecture and modeling capabilities.
Simulation technology is an important tool for planning, implementing, and operating complex technical systems.

Several trends in the economy lead to shorter planning cycles. These include:
- increasing product complexity and variety,
- increasing quality demands in connection with high cost pressure,
- increasing demands regarding flexibility,
- shorter product life cycles,
- shrinking lot sizes,
- increasing competitive pressure.

Thanks to the Tecnomatix Plant Simulation program, it is possible to create and visualize in 3D using the included libraries or external CAD data. Use the JT data format for 3D modeling and Siemens direct model technology to efficiently load and realistically visualize large 3D simulation models without compromising on simulation and analysis.

With the architectural advantages of encapsulation, inheritance, and hierarchy, manage, understand, and maintain complex and detailed simulations much better than conventional simulation tools.

Modeling uses objects within objects and models within models at all hierarchy levels. Items stored in libraries are maintained for all users, and changes are automatically applied to all instances of those items regardless of where they are used. And these library items can be easily configured according to the specific requirements of a particular simulation.

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2. TestBED 4.0

TestBed 4.0 is a specialized workplace, oriented towards solving the practical needs of industry in the field of Industry 4.0, creating cooperation between industry and universities, and involving young talented students in solving the practical needs of the practice. The ambition of TestBed 4.0 is to provide real outputs, information, and support for industrial enterprises, and to develop knowledge in the field of Industry 4.0 (Fig.1).

TestBed is intended for:

- industry with discrete production,
- small, medium, and large companies,
- universities and their staff and students,
- those interested in the practice.

TestBed 4.0 expects the involvement of the industry in listing topics for final theses or small commercial projects that can be solved independently by students or under the guidance of TestBed specialists. Doctoral students are also considered students, whose expertise usually guarantees the ability to independently solve even more complex tasks.

Fig.1 TestBed 4.0

3. TECNOMATIX PLANT SIMULATION

Tecnomatix Plant Simulation software enables the simulation, visualization, analysis, and optimization of production systems and logistics processes (Fig.2). Using Plant Simulation enables companies to optimize material flow, resource utilization, and logistics for all levels of plant planning. The simulation tool can be leveraged to analyze global facilities, an entire plant, or simply a few machines in a production line.

In times of increasing cost and time pressures in production along with ongoing globalization, logistics has become a key factor in the success of a company. The need to deliver on time and in sequence, introduce lean manufacturing principles, plan, and build new sustainable production facilities, and manage global production networks requires objective decision criteria to help management evaluate and compare alternative approaches. Plant Simulation helps to create digital models of logistics systems so companies can explore system characteristics and optimize their performance. The digital model not only enables users to run experiments and what-if scenarios without disturbing an existing production system, but it can be used in the planning process long before the real system is installed. Extensive analysis tools, statistics, and charts let users evaluate different manufacturing scenarios and make fast, reliable decisions in the early stages of production planning.

Plant Simulation helps manufacturers to:

- Detect and eliminate problems that otherwise would require costly and time-consuming corrective measures during production ramp-up.
- Minimize the investment cost of production lines without jeopardizing the required output.
- Optimize the performance and energy usage of existing production systems by taking measures that have been verified in a simulation environment prior to implementation.

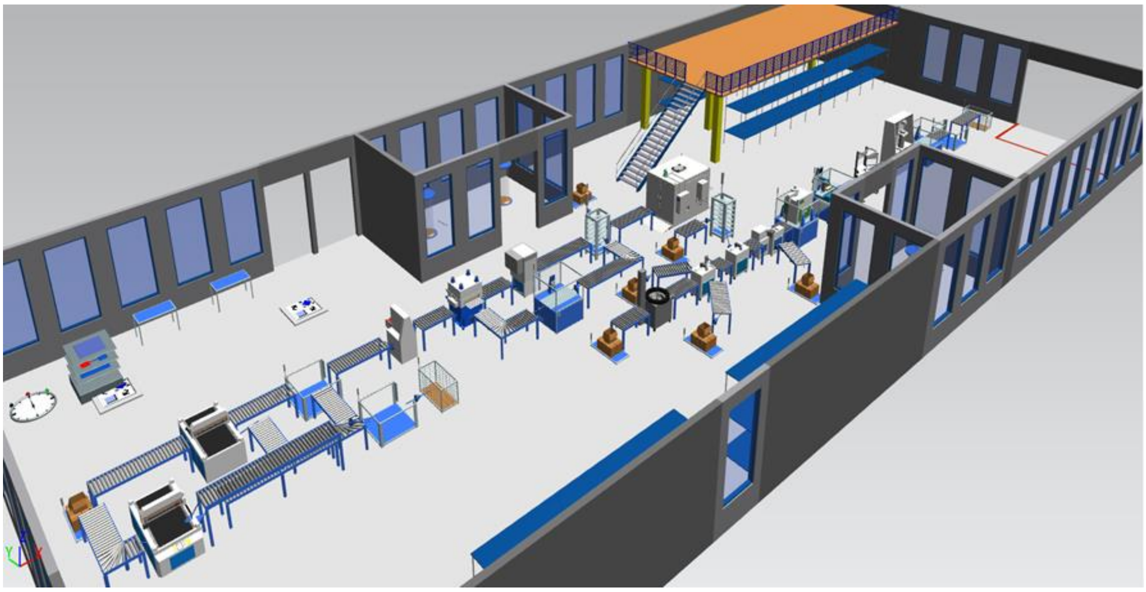


Fig.2 Virtual production line environment in the Tecnomatix Plant Simulation program

4. CONNECTION OF TECNOMATIX PLANT SIMULATION AND KEPserverEX SOFTWARE COMPONENTS

KEPServerEX is a software solution developed by Kepware Technologies (now part of PTC) that serves as a communication server for industrial automation systems. Its main role is to ensure communication between different devices and software applications in industrial environments.

KEPServerEX can communicate with various devices and network protocols such as PLC (Programmable Logic Controller), RTU (Remote Terminal Unit), DCS (Distributed Control System), CNC (Computer Numerical Control), as well as protocols such as OPC (OLE for Process Control), MQTT (Message Queuing Telemetry Transport), Modbus, SNMP (Simple Network Management Protocol), Siemens S7, Allen-Bradley, and many others (Fig.3).

With KEPServerEX, you can retrieve data from devices and distribute it to various software applications such as visualization tools, historical databases, building management systems, analytics tools, and more. It also supports functions such as data collection, device status monitoring, alarms, and events.

KEPServerEX is widely used in industries such as manufacturing automation, energy, transportation, food and beverage, water management, and many others. It is known for its reliability, flexibility, and ability to integrate with different technologies and systems.

Fig.3 KEPserverEX connection options

First of all, after opening the KEPServerEX program, we click on "Project" in the menu on the left and create a "New Channel". After creating a "New Channel", the option "Select the type of channel to be created" will appear and we will select the option "Simulator" (Fig.4).

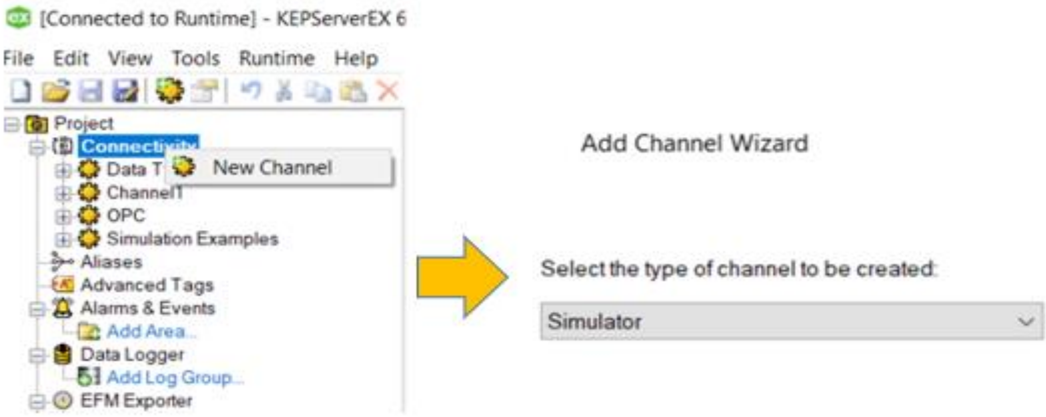
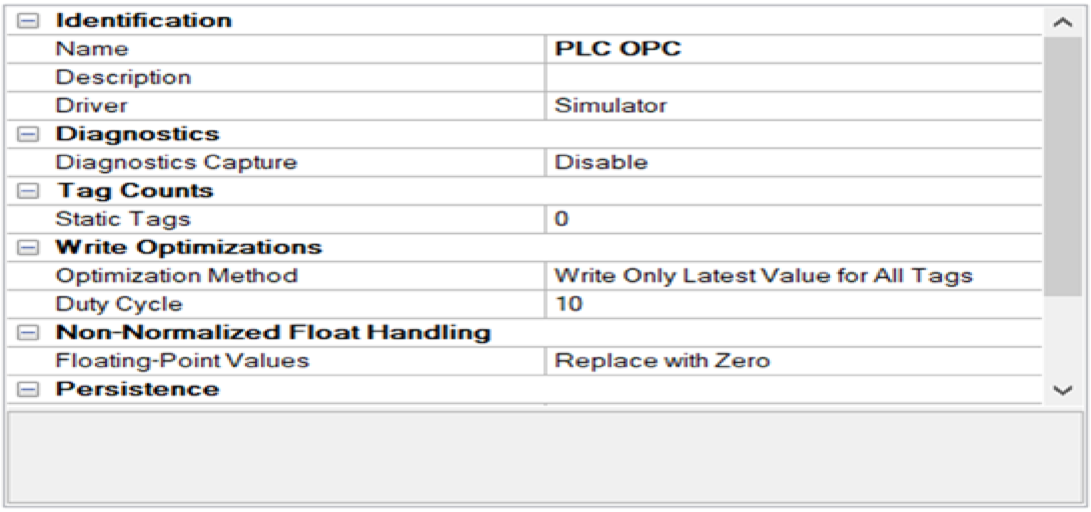


Fig.4 Creating a "New Channel"

The next step will be naming "Specify the identity of this object", where we enter the name of the "object" (Fig.5).

Fig.5 Name of the object

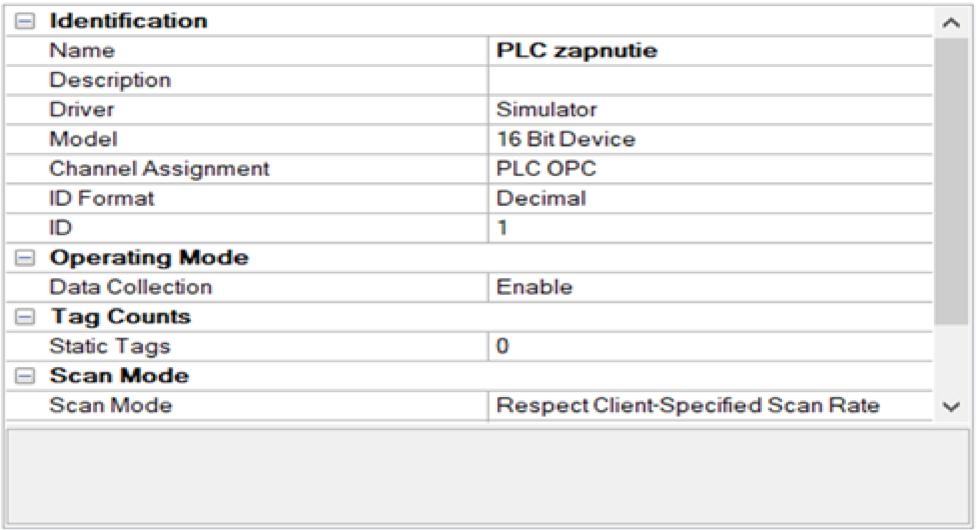
When setting individual program options, it is necessary to define the method of sending invalid floating point numbers to the client. The setting is set to "Replace with Zero". Item Persistence needs to be switched to "Disable". The last step in the settings options is the definition of the address where the information will be stored. A summary of the settings is shown in Fig. 6.



Identification	
Name	**PLC OPC**
Description	
Driver	Simulator
Diagnostics	
Diagnostics Capture	Disable
Tag Counts	
Static Tags	0
Write Optimizations	
Optimization Method	Write Only Latest Value for All Tags
Duty Cycle	10
Non-Normalized Float Handling	
Floating-Point Values	Replace with Zero
Persistence	

Fig.6 Summary of set values and names

After creating a "New Channel", to which we set the name PLC OPC, click on this "channel" and create a "Device". Subsequently, it is necessary to set the specific device type, input format, and method (Fig.7).



Identification	
Name	**PLC zapnutie**
Description	
Driver	Simulator
Model	16 Bit Device
Channel Assignment	PLC OPC
ID Format	Decimal
ID	1
Operating Mode	
Data Collection	Enable
Tag Counts	
Static Tags	0
Scan Mode	
Scan Mode	Respect Client-Specified Scan Rate

Fig.7 Summary of set values and names

After the settings, it is possible to link the programs. If all 4 parts from the input arrive in the "parallel milling" process, only then will this process be turned on and a signal will immediately be sent to the CNC device and the production process will be turned on (Fig.8).

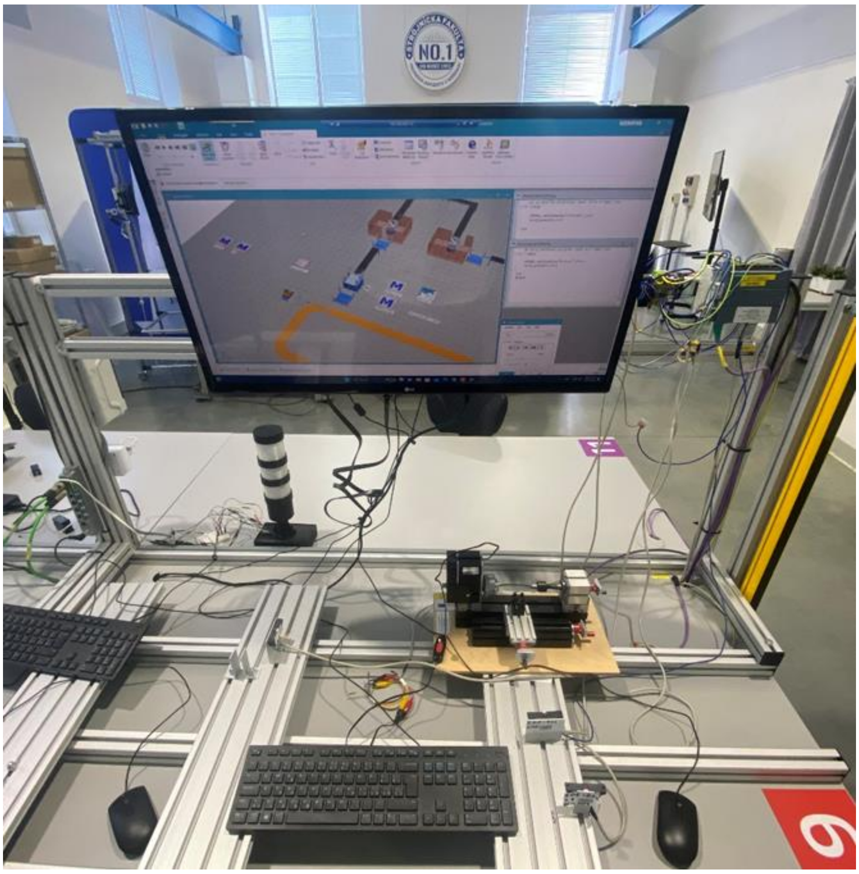


Fig.8 Means for the implementation and connection of the simulation with the real environment

5. CONCLUSION

The goal was modeling and simulation of production processes in collaboration with technologies in the TestBed 4.0 laboratory. As part of practical use, a visual part of our own production line was created using the Tecnomatix PlantSimulation program from the Siemens company, in which we then described the setup of the entire production line in individual steps.

In the TestBed 4.0 laboratory, we worked on connecting the PlantSimulation program and the PLC, for which I used KEPserverEX. This program is used to create a server and then connect it with the Tecnomatix PlantSimulation program, which communicates with each other and transfers data. Thanks to this communication and data transfer, it was possible to fulfill the goal of this work, which was to connect PlantSimulation and PLC and then connect the CNC equipment. The result is a functional link that helps the simulation environment gain added value and present the simulation features in a reduced form in the real world.

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SIGNIFICANCE OF DIGITALIZATION ON THE EFFECTIVENESS OF SMEs

Abstract

The pandemic's impact on businesses continues, driving increased adoption of digital technologies. Recognizing SMEs' significance, the European Commission emphasizes digitalization support. Our study explores the impact of digitalization on SME performance using data from 27 EU countries. The literature review examines the relationship between digitalization and SME performance. Findings offer insights for policymakers to integrate digital tools into SME infrastructure and inspire future research.

Key words: SMEs; Digitalization; Analysis; Significance

1. INTRODUCTION

European industry is strongly committed to embracing digitalization as a means to enhance competitiveness in the face of globalization. The COVID-19 pandemic has expedited this process, impacting businesses across all sectors. To adapt, companies have had to implement new internal workflows and expand their presence in digital channels. This rapid transformation has led to significant changes as businesses swiftly adopted digital solutions [1]. The utilization of digital technologies enables the implementation of novel processes throughout the entire value chain, spanning production, sales, and services. A study conducted by [2] explored the digitalization processes within various industries, particularly their influence on the performance of small and medium-sized enterprises (SMEs). The findings indicated a correlation between the introduction of information technology (IT), digitalization, and financial performance. The study identified key factors driving digitalization, including IT deployment, employee skill enhancement, and digital strategy. Furthermore, IT was recognized as a crucial factor impacting financial performance through digitalization.

According to the European Commission, SMEs comprise over 99% of all businesses in the European Union (EU) and contribute to approximately two-thirds of total employment. They play a significant role in the EU's gross domestic product (GDP), accounting for over half of the added value in the non-financial corporate economy [3]. Despite the considerable impact of the COVID-19 pandemic on SMEs throughout the EU, businesses have demonstrated resilience and adaptability in the face of these challenges [4]. Various measures, such as regulatory relief, financial aid, and targeted programs to support digitization and innovation, have been implemented to support SMEs.

The objective of this study is to examine the relationship between digitalization and business performance, aiming to determine whether companies that embrace digital transformation tend to be more prosperous and achieve higher performance. To explore this connection, a sample of 27 member countries of the European Union (EU27) was considered, utilizing a regression model for panel data with a 5-year timeframe (2017-2021). This research contributes to the existing literature by enhancing the understanding of variables that influence the digitalization of businesses and providing empirical evidence on how the integration of digital technologies impacts the performance of SMEs.

2. LITERATURE REVIEW

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The concept of Industry 4.0, also known as the Fourth Industrial Revolution, revolves around a business strategy that entails implementing digital technologies at the enterprise level [5,6]. This development has had a profound impact on all aspects of corporate operations, necessitating the adoption of new technologies to maintain competitiveness in an ever-evolving market [7,8]. Embracing technology enables companies to establish a strong competitive advantage, enabling them to differentiate themselves from their rivals [9]. The ongoing process of digital transformation involves digitizing production systems, automating processes, and connecting production sites to facilitate the seamless exchange of information and data [10]. Moreover, within supply chains, new technologies influence communication-related aspects of business models [11]. The extent of digital transformation varies among companies depending on their respective industries. In addition to the sector they operate in, the degree of digital transformation depends on factors such as the level of technology adoption, evolving customer needs, and market size [12]. Companies that embrace digitalization at the forefront demonstrate greater long-term productivity and revenue compared to those with lower digital orientation [13]. Small and medium-sized enterprises (SMEs) can leverage digital technologies to support their business functions, such as utilizing social media applications, open-source software, mobile security, and e-commerce platforms for marketing purposes. Additionally, they can employ video conferencing, instant messaging, and shared calendars. These digital tools may involve paid or free usage options [14, 15]. Furthermore, other tools aimed at enhancing SME performance, including Big Data, Blockchain, Artificial Intelligence, and the Internet of Things, have potential economic, social, and environmental benefits [16].

The utilization of digital technologies can contribute to financial inclusion for SMEs by facilitating quicker access to the necessary financial resources. A study conducted in 2019 examined the role of digital microfinance services in improving SMEs' financial access, revealing that such services significantly aided managers and owners in seamlessly managing their finances and transactions [17, 18]. The study also highlighted the need to expand the range of financial products available on digital platforms and reduce the costs associated with digital financial services. Another study in the same domain emphasized that integrating financial technologies and innovations into traditional business models can expand SMEs' loan access [19]. Numerous studies have affirmed that diversifying sources of financing has a positive impact on business performance. Thus, increasing SMEs' access to alternative funding sources, apart from traditional ones like bank loans, could stimulate their performance [19, 20]. Similarly, a study conducted in 2022 underscored that SMEs with expanded access to and utilization of new technologies have a greater likelihood of securing financing from banks [21].

Drawing upon the collected evidence and in alignment with the prior examination of literature, a research query was devised to investigate the influence of digitalization on the performance of small and medium-sized enterprises (SMEs): *"To what extent does digitalization affect the performance of SMEs?"*

3. RESEARCH METHODOLOGY

Our study involves conducting an econometric analysis using panel data to examine and evaluate the impact of digitalization on the performance of SMEs, aiming to address the research question. The sample under examination comprises 27 member states of the European Union (EU). To conduct this analysis, we have constructed a panel dataset covering a period of five years, ranging from 2017 to 2021. The utilization of the Longitudinal Data or Panel Data approach has been chosen as it allows for tracking the same individuals over time, facilitating the examination of dynamic responses and controlling for unobserved heterogeneity. This method is particularly suitable when dealing with data that contains both cross-sectional and time series elements [22]. For the statistical analysis, EViews 12 statistical software was used, and the dataset integrated observations from the EU27 countries, considering the interaction of various variables. Table 1 presents the four variables utilized in this analysis.

Tab. 1 Variables for descriptive statistics

Dependent Variable	**Definition**	**Unit**
Employment	total employment of SMEs in EU27	%
Independent Variables		
Digital intensity index (DII)	A tool for evaluating the digital maturity and competitiveness of EU27 SMEs	%
Control variables		
GDP growth	Measured as percentage change	%
Total investment	Percentage of GDP for each of the EU27 countries	%

Considering that SMEs employ around 98% of all businesses in EU27 and provide jobs for over 93 million individuals, constituting 67.4% of total employment in the non-financial business economy, the overall employment within SMEs in EU27 holds tremendous significance [23]. These businesses serve as a vital source of employment and contribute to the overall advancement of SMEs in EU27. The employment situation within SMEs plays a crucial role in their performance and overall success. Companies that effectively manage their workforce can reap benefits such as innovation, increased productivity, and enhanced competitiveness, while those that struggle in this aspect may encounter limitations and challenges. The Digital Intensity Index (DII) serves as a valuable tool for assessing the digital maturity and competitiveness of businesses in the digital era. It enables organizations to streamline and enhance their processes, improve outcomes, and optimize resource utilization. This index facilitates comparisons of digital maturity levels and the extent of digital technology implementation, aiding in identifying areas for improvement and promoting business growth. The data for our study is sourced from DESI (2017-2021) [24].

The independent variables will play a crucial role in addressing the research question and validating or refuting our hypotheses, which are integral in assessing the extent of digitalization among SMEs in the EU. Additionally, we have identified the dependent variables as the share of value-added and employment, both of which are widely regarded as fundamental performance indicators in businesses.
In order to address our research question, we will employ a linear regression model that is constructed using regression equation (1). This equation incorporates both the dependent and independent variables. By utilizing this model, we aim to elucidate the relationship between the independent variable and its impact on the dependent variable, examining how changes in the independent variable can lead to corresponding changes in the dependent variable.

$$Y_{it} = \alpha + \beta X_{it} + \varepsilon_{it} \tag{1}$$

Where:
- Y is dependent variable;
- α je intercept (value, that Y has when X=0);
- β je slope of the line;
- X is the independent variable;
- ε is white noise;
- it - „i" number of observations a „t" time-series on which the data was collected.

Using equation (1) as the foundation and taking into account the quantity of dependent and independent variables, the resulting equations in our study can be expressed as follows:

$$EMP_{SMEs} = \alpha + \beta_0(DII_{DESI}) + \beta_1(GDP_{growth}) + \beta_2(Total\_inv) + \varepsilon_{it} \tag{2}$$

Where:
- EMP_{SMEs} is dependent variable;
- DII_{DESI} is independent variable;
- GDP_{growth}, $\mathrm{Total\_inv}$ are control variables;
- β_1 a β_2 are the coefficients of the independent variables.

The objective of regression analysis is to examine the association between independent and control variables with the dependent variable. To determine the appropriate model specification, including whether to utilize pooled data or account for heterogeneity through fixed effects or random effects, we conducted various tests. Fixed effects are employed to assess whether there are distinct intercepts for each entity, and if these intercepts remain constant over time. This approach assumes that the relationships between explanatory and dependent variables are consistent on average and over time, making specific assumptions about the independent variable and error distribution. On the other hand, random effects focus on capturing effects beyond specific values of the independent variable, eliminating the need for precise assumptions about the variables [25]. Our proposed model aims to comprehend the relationship between the DESI index and the value added of SMEs. To confirm the required effects of the model, we will conduct a set of tests on the data. In order to determine whether to use fixed effects or random effects in our model specifications, we will perform a Hausman test.

4. RESULTS AND DISCUSSION

In order to examine the dispersion of values in our analysis, we will present descriptive statistics of the variables utilized. We will provide measures such as the mean, median, and standard deviation, which serve as indicators of the proximity of data points to a normal distribution. When data follows a standard or Gaussian distribution, the mean and median tend to be close to each other. Upon reviewing Table 2, we observe that all variables in the model exhibit means and medians with comparable values, indicating that all variables are assumed to be normally distributed.

Tab. 2 Descriptive statistics of variables, Source: Own calculation in EViews 12

Variable	**Mean**	**Median**	**Standard Deviation**
Employment	73,592	74,800	5,55
DII	54,460	52,700	14,402
GDP growth	2,038	2,900	4,095
Total investment	22,141	22,500	2,980

Table 3 displays the correlation matrix, indicating that no correlation exceeding 0.7 or falling below -0.7 was identified. As a general guideline, this suggests the absence of significant correlations among the variables [26].

Tab. 3 Correlation matrix, Source: Own calculations in Eviews 12

Variable	Employment	DII	GDP growth	Total investment
Employment	1			
DII	0,479	1		
GDP growth	0,106	-0,070	1	
Total investment	0,395	0,167	0,243	1

As the subsequent step, we will conduct a Hausman test in order to determine the appropriate method for conducting regression analysis on the data. The Hausman test examines the following hypotheses:

- H0 = random effects model is more appropriate for this study.
- H1 = fixed effects model is more appropriate for this study.

Based on the information presented in Table 7, the calculated p-value is below the significance level of 0.05, or 5%. Consequently, we reject the null hypothesis (H0) and accept the alternative hypothesis (H1), indicating that the fixed effects model is more suitable for our study.

Tab. 4 Hausman test, Source: Own calculation in Eviews 12

Chi-Square Statistic	7,566
Chi-Square Statistic Probability	0.042

The conclusive outcomes of the panel data regression analysis employing the cross-section fixed effects model and the LSDV method are presented in Figure 1. The analysis reveals that the coefficient of the independent variable (DII) is statistically significant, as evidenced by its significant estimate at the 1% level of significance. This value means that, on average, for each one unit increase in DII, the employment would increase by 0.0865 units according to the data sample (ceteris paribus).

Dependent Variable: EMPLOYMENT
Method: Panel Least Squares
Date: 05/28/23 Time: 14:17
Sample: 2017 2021
Periods included: 5
Cross-sections included: 27
Total panel (balanced) observations: 135

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	59.39518	2.228996	26.64661	0.0000
DII	0.086495	0.012390	6.981184	0.0000
GDP_GROWTH	0.053761	0.021186	2.537537	0.0126
TOTAL_INV	0.423518	0.109206	3.878151	0.0002

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.978682	Mean dependent var	73.59259
Adjusted R-squared	0.972794	S.D. dependent var	5.554085
S.E. of regression	0.916109	Akaike info criterion	2.855766
Sum squared resid	88.12178	Schwarz criterion	3.501383
Log likelihood	-162.7642	Hannan-Quinn criter.	3.118127
F-statistic	166.2185	Durbin-Watson stat	1.419381
Prob(F-statistic)	0.000000		

Fig. 1 Panel data regression results, Source: Own calculation in Eviews 12

The results demonstrate the statistical significance of the independent variables, as indicated by the R-Squared and Adjusted R-Squared values. The R-Squared value for the regression model is 0.978682, representing the percentage of variance in the dependent variable that can be explained by the independent variable. This value ranges from 0 to 1, where 0 indicates that the independent variable has no explanatory power for the dependent variable, and 1 signifies that the independent variable (DII) we are considering perfectly explains the dependent variable (employment). The obtained R-Squared value in our case is relatively high, indicating a strong relationship between the variables and highlighting the statistical significance of the regression model. Therefore, we can conclude that the model supports a positive causal relationship between the variables.

Ensuring measurement validity (construct validity) was a crucial aspect of this study as it aimed to capture accurate measurements that align with the concept being investigated. An inherent challenge in quantitative research is the potential for inaccurate measurement of variables. To address this issue, we employed control variables that have a strong theoretical and empirical connection to the topic.

The adoption of digital technologies by SMEs offers opportunities to develop unique resources, enhance efficiency, and increase productivity, thereby gaining a competitive edge over relentless competition. Furthermore, digitalization can facilitate the acquisition of new competencies, skills, and knowledge, empowering businesses to introduce innovative processes and products. However, SMEs often encounter obstacles when adopting digital technologies due to limited financial and human resources. While financial constraints are a significant consideration, we are not primarily concerned about the influence of control variables related to finances on the overall outcome, as these variables are not the central focus of our study. Our selection of control variables was carefully made, considering their impact on the dependent variables. However, it is important to note that these variables share their influence with numerous other indicators. Given the limited financial resources of SMEs, these selected control variables still hold relevance within the context of our study.

Based on the validity of our findings, we can confidently affirm that the independent variable (DII), which represents the level of digitalization in EU27 SMEs, has a substantial and statistically significant influence on the dependent variable (employment), which serves as an indicator of SME performance in EU27. This confirms the presence of a mutual causal relationship between these variables, effectively addressing our research question.

5. CONCLUSION

Our study aimed to examine the impact of digitalization on business performance, focusing specifically on SMEs in the EU27 from 2017 to 2021. We gathered datasets for both the dependent variable, which represents business performance, and the independent variable, which represents the level of digitalization among SMEs in the EU27 during the specified time frame. To conduct our analysis, we transformed the collected individual variable datasets into panel data, which was essential for regression analysis. The statistical software EViews 12 was utilized for the analysis, chosen based on the nature of the data, applicable tests, and the study's objectives.

The results of our panel data analysis indicate that the degree of digitization within SMEs can contribute to increased employment and have a significant impact on their overall performance in the EU27. However, it is important to consider that the study period encompassed the effects of the COVID-19 pandemic, which imposed certain limitations on traditional business development and prompted a faster adoption of digital solutions. We believe that our research findings can inspire future studies and provide valuable insights for researchers and policymakers, highlighting the substantial role of digitalization in enhancing SME performance. One of the main limitations of our research was the availability of data for indicators measuring SME performance. In future research, it would be beneficial to expand the sample to a global scale, enabling access to a wider range of variables that measure both digitalization and business performance.

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NECESSARY COMPONENTS OF AN INNOVATIVE ORGANIZATION

Abstract

The success or failure of innovative activities is crucially determined by the value placed on innovation processes by the management of a company. For this reason, the management level needs to promote and esteem creativity and ideas throughout all levels of staff as well as undertake on---going investments in organizational modifications. It is important to create operating conditions which promote innovation to make use of the human and relational capital of all actors at every single level within a hierarchy.

Key words: max. innovation, innovative organization,

1. INTRODUCTION

Each business operates in a different environment that requires different characteristics and structure. That is why there is no ideal guide to how an innovative enterprise should behave and what structure it should have. Nevertheless, there are certain key components that an enterprise should have in order to be able to innovate successfully and regularly [1].

2. COMPONENTS OF THE INNOVATIVE ORGANIZATION

At the heart of innovation is the process of learning and change. This process is often risky and costly and represents a disruptive moment in the life of a company. This is why some businesses choose to maintain the status quo rather than innovate. Innovation requires energy to overcome this comfortable state and a commitment to change [3, 5]. For this to happen, a business needs to implement a set of components that are characteristic of innovative organizations. Implementing them is not easy and often requires fundamental changes. In Tab. 1 are summarized components of an innovative organisation.

Tab. 1 Components of an innovative organisation [8, 11]

Component	Key features
Shared vision, leadership and will to innovate	A clearly articulated and shared sense of purpose for action/innovation. Extension of strategic intentions. Top management commitment.
Suitable structure	A structure that allows for creativity, learning and interaction. The key is to strike a balance between an organic and mechanistic approach in the circumstances.
Key individuals	Individuals who drive or otherwise support innovation - the so-called innovation champions.
Effective teamwork	Appropriate use of teams at the local, interdepartmental and inter-organisational levels.
Continuous individual development	Long-term support for training and up-skilling of staff to achieve a high level of competence and capability.
Wide communication	Inside the organisation and out of the organisation.

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	Within the organisation in three directions - upwards (from workers to management), downwards (from management to workers) and laterally (between workers, divisions, departments, etc.).
High level of involvement in innovation	A culture of organization-wide continuous improvement activity.
External focus	Orientation to internal and external customers.
Creative climate	A positive approach to creative ideas, supported by appropriate incentive systems.
A learning organisation	A high level of engagement in proactive experimentation, finding solutions to problems, communicating and sharing experiences, acquiring and disseminating knowledge - both within and outside the organisation.

1.1 Vision, leadership and will to innovate

One of the issues that a successful innovative organization should address is finding ways to ensure that individuals with good ideas are able to develop their ideas and do not have to leave the company because of them. The foundation of innovative organizations is therefore a shared vision that motivates employees to actively come up with innovative ideas and have enough space to be able to implement them in the enterprise. The enterprise should strive to ensure that the corporate culture fosters an innovative spirit and that there is a will to innovate among employees [2].

Top management commitment also plays an important role. But the question is how to find the right mechanism to create and show others real engagement, enthusiasm and management support. Above all, there is a need for long-term support for those innovative projects that have many uncertainties in them and therefore may have a longer-term return than originally anticipated. It is in such situations that sustained management support is essential for the existence of the project and its further development.

1.2 Structure

No matter how well systems for implementing innovation are developed in a company, they will not work well without an appropriate organisational structure. However, achieving such a structure is not easy. Indeed, it is necessary to put in place a structure and processes that facilitate the implementation of technological or other changes in the enterprise. For example, hierarchical enterprises in which communication is predominantly one-way top-down are unlikely to create a supportive environment for information flows and interdepartmental collaborations. Other factors that influence organizational structure include the size, age, and strategy of the company and the environment in which the firm operates. The greater the uncertainty and complexity of the environment, the greater the need for flexible structures that support innovation [4].

1.3 Key individuals

Another important element is the existence of key individuals who support innovative designs and processes. The uncertainty and complexity characterise most innovation proposals that can cause promising proposals to be prematurely terminated before they reach the implementation phase. This problem can be solved by the presence of a key person (or group of persons) who stands firmly behind the innovative proposal, pushes it forward and sacrifices energy and enthusiasm to get it through the company's decision-making system. It is such personalities, who are able to champion new projects, who are behind many famous innovations [6].

Such persons play several roles in the process of innovation implementation. First, they can be a source of critical technical knowledge. In addition to their technical knowledge, their contribution can also lie in inspiring and motivating other employees, as well as in their commitment as a role model for colleagues. A second important role is organizational support, which consists of supporting the innovation proposal in obtaining the necessary funding or convincing sceptical critics from management. The third key role is that of a team member, especially the project team leader. The right choice of team manager is fundamental to the success of an innovative project. It is always necessary to choose a team manager in accordance with the requirements of the situation and the nature of the project.

1.4 Support for training and staff development

The high amount of money that businesses invest in the training and personal development of their employees is another key feature of organisations that achieve excellent results over the long term. Numerous studies at national and regional level show a direct link between investment in training and a company's capacity for innovation. This is probably due to the greater ability of workers to use modern technologies and practices that directly support the implementation of innovation [9].

While equipping people with the skills they need to master these modern elements and be able to use them in practice is important, training and development can have a much broader role. For example, it serves as an important motivator. Employees value the opportunity to learn and acquire new knowledge, which has a positive impact on their engagement. Some recent surveys have also shown that employees value opportunities for personal development more than financial incentives among reward mechanisms. Superior training also promotes the willingness of workers to take on more responsibility and initiative. It is these positive influences that promote the innovativeness of the enterprise.

1.5 High involvement in innovation

Every employee of a company has basic creative skills. If an organisation manages to find a mechanism that can harness these skills properly and regularly, the resulting innovation potential can be enormous. Although individual workers may be able to generate only limited innovation, the sum of their efforts can yield significant positive results. An example of such a mechanism is kaizen. "Kaizen is a continuous improvement practice (mechanism) that originally originated in Japan." This practice was presented in detail in the book "Kaizen: The Key To Japan's Competitive Success" published in 1986 by Masaaki Imai.

Today, kaizen is globally perceived as a pillar of long-term organizational strategy and innovation. Kaizen is guided by several basic principles [7]:

- Good processes produce good results.
- Understand and grasp the current situation through personal experience.
- Use data and facts in management.
- Emphasize teamwork.
- Uncover and remove the root of the problem, etc.

Another positive aspect of high employee involvement in innovation is their willingness to accept or even implement the proposed changes, thus helping the company to minimise the negative impacts associated with the introduction of change.

Increasing recognition of the potential of innovation with high worker engagement has changed the question of innovation management from whether to pursue such a system to how to achieve it. Based on experience, the challenge is not so much building the system, but then keeping it running long enough. It is this issue that I will address in the next section of my paper [14].

Previous research on organisations that have a high quality innovation system with high worker engagement shows certain stages that companies had to go through to build a high quality system. Each stage takes a certain amount of time, which can vary from one enterprise to another. In Tab. 2 are stages of development of high involvement in innovation.

Tab. 2 Stages of development of high involvement in innovation [10, 15]

Stage of development	Typical characteristics
1) Unconscious involvement	Sporadic problem solving. Absence of formal structures or processes. Irregular bursts of activity punctuated by inactivity. The dominant model is that of problem solving by specialists. Short-term benefits. Lack of strategic influence or impact.
2) Structured wiring	Formal attempts to establish and maintain high engagement.

	Using a formal process for problem solving. Worker participative approach. Training in basic engagement tools. Organised system for processing improvement proposals. Reward incentive system for employees.
3) Goal-oriented engagement	All points from the second stage. Formal implementation of strategic objectives. Monitoring and measuring the innovations introduced against these objectives. Line management system.
4) Proactive engagement	All points from the third stage. Responsibility for the system is delegated to the implementation units. Internally controlled wiring (without external control). High level of experimentation.
5) Full high involvement in innovation - a learning organisation	High involvement in innovation is the predominant way of working. Automatic information and knowledge gathering and sharing. Every employee is actively involved in the innovation process. Presence of incremental and radical innovations.

The first stage is characterised by the occasional involvement of staff in minor problem solving. However, there is no formal procedure to coordinate and support this process. The innovations that emerge at this stage therefore do not bring any substantial benefits. In the second stage, the company initiates the first serious attempts to mobilise employees and involve them in innovation. With the necessary management support, the enterprise introduces formal processes for solving problems in a systematic way. This includes training and encouraging employees to use these processes and setting up a reward system to motivate employees. The enterprise should strive to implement ideas as intensively as possible to demonstrate their importance and thus create a habit of high involvement in innovation. The process is already starting to produce more significant results, but these are mostly concentrated at the local level and lack strategic relevance. At this point, the enterprise needs to take the whole process to a higher level [13].

The third stage links the established habit of high involvement in innovation to the strategic goals of the enterprise. This is why the enterprise needs to put in place two other key activities: strategy implementation and strategy monitoring and measurement. Strategy implementation in practice means that the overall corporate strategy is presented throughout the organisation and broken down into specific measurable objectives. Against these, all activities in the context of engaging in innovation are then directed. The implementation of the strategy is directly linked to the need to monitor and measure the performance of the whole innovation engagement process. The company to further improve the process and motivate the staff uses the results of the measurement. In the third stage, high involvement in innovation already brings significant benefits to the overall economic performance of the organisation.

A limitation of the third stage is that the focus of individual activities is still largely dictated by management. While activities take place at different levels and are carried out by individuals, small and large teams, they are still controlled from the 'outside' (management). The fourth stage is therefore characterised by the involvement of an additional element: the empowerment of individuals and teams to experiment and develop their own initiatives. Although not a simple step, employee empowerment builds the principle of 'internally directed' involvement in innovation as opposed to management externally directing activities. This significant change enables and encourages open and continuous learning. Thus, there is the emergence of a fast learning organisation where knowledge is actively shared and used [16].

The fifth stage culminates in building an organisation with high involvement in innovation. Every employee is involved in experimentation and process improvement. In the fifth stage, the enterprise must strive to create a certain set of values that will unite employees and allow them to actively participate in the development of the enterprise. In Fig. 1 are displayed stages of building a high-involvement organisation and performance.

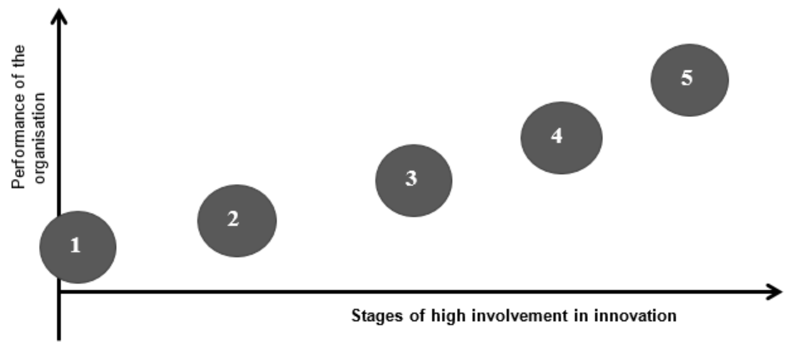

Fig. 1 Stages of building a high-involvement organisation and performance [12]

1.6 Effective teamwork

Teamwork is based on the principle that "innovation is primarily a combination of different perspectives to solve a problem." A group or team is more capable of offering more than an individual, especially when generating new ideas or developing solutions. These highly effective teams do not arise by chance. Their emergence is due to the right selection of team members in terms of the specific task and context, investment in team building, quality leadership and the right division of tasks. Above all, effective team building is a critical factor in project success. The team leader should know his/her team members very well, actively cement them and distribute tasks according to their strengths and experience. Key elements of effective teamwork include [8]:

- Accurately defined tasks and objectives.
- Effective team leadership.
- The balance of team roles and their consistency with individual behavioural styles.
- An effective mechanism for problem solving within the team.
- Maintaining the cooperation (relationship) with the external organisation.

To get a team to a stage where it is capable of effective teamwork and delivering significant results requires significant effort . This is because every team tends to go through several phases in which the team leader has to apply various management and leadership practices and skills. These phases are:

- Forming: the phase in which most members are positive. Workers are getting to know each other and preparing for their role in the team, but it is not yet completely obvious to them. The team leader plays a dominant role as the roles of the individual members are not yet clearly defined.
- Storming: team members begin to rebel and criticize the boundaries that were set in the previous phase. Some try to assert themselves and get the group to meet their personal needs and adapt to their style of working. The authority of the team leader is often challenged. The manager's role is to minimize these conflicts and ensure that there is sufficient room for feedback and mutual understanding within the team.
- Norming: over time, the team reaches a stage where people begin to respect each other, appreciate each other's strengths, and accept the role of team leader. Shared values, expectations and ways of doing things are established. Team members begin to help each other and unite toward team goals.
- Performing: Relationships within the team are stabilized and members work effectively for the benefit of the whole. The team is accomplishing its goals with the support of the structures and processes that were established in the previous phase. The team leader can delegate most tasks and focus on developing team members and stimulating creativity and innovative thinking.

1.7 Creative climate

Any business that seeks to build an organisation with a high commitment to innovation must create an environment in which the creativity of the workforce is encouraged. First, it must remove the environmental factors that contribute to stifling innovation [11]:

- The dominance of constraining vertical relationships.
- Poor lateral communication.
- Limited tools and resources.

- Direct orders from the top (leadership) down.
- Formally constrained change mechanisms.
- Fostering a culture of inferiority (example: innovation is only good if it comes from management).
- Innovative activity without a clear goal.

The impact of these factors creates a behavioural norm that limits creativity and leads to a culture in which innovation does not thrive. By removing these factors, the organisational culture changes.

3. CONCLUSION

Today, characterised by massive competition and market instability, innovation and its proper management are the foundation of a company's success. They help it to maintain a competitive advantage and cope with the ever-changing environment in which it operates. We can therefore argue convincingly that innovation is the driving force behind the development of every company today [2].

Innovation management is a relatively new direction of management. The concept is widely used because science, technology and innovation have become a key factor in economic strategies and competition in markets in developed countries. Innovation management is associated with the professional implementation of the management function primarily at the enterprise level. In particular, it should be stressed that innovation management has an organic link with the phenomena that once gave rise to the concept of strategic management. It studies a number of special laws and requirements for the management of modern corporations and business development [7].

The need for innovative enterprise development places new demands on the organisation, content and methods of management activities. The organisation of innovation management in an enterprise is a system of measures aimed at rational integration of all its elements into one innovation management process. The innovation management organisation combines the above elements of the innovation management process into a single system.

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THE IMPORTANCE OF LOCOMOTION IN A VIRTUAL TRAINING

Abstract

The presented article deals with the issue of movement in the immersive virtual environment. Many different types of this movement can be utilized in virtual reality education methods – virtual training. The article focuses on teleportation, as one of the most used methods of locomotion, and the omnidirectional VR treadmill, as one of the newest additions. These two are compared in a small study while inquiring which type is preferred by the users.

Key words: virtual reality, education, locomotion

1. INTRODUCTION

Virtual reality (VR)is becoming cheaper, more powerful and more accessible for businesses, but also for the average user. However, there are still several obstacles that prevent the full implementation of virtual reality in some industries [1,2]. Fortunately, the increased interest in this technology has renewed interest in researching and finding solutions to these problems. In any potential implementation of this technology, it is also necessary to deal with possible shortcomings and limitations. One of these problems may be the correct selection of locomotion in VR application development. Teleportation seems as the best compromise for the effective and safe VR movement type.

2. LOCOMOTION

Locomotion is the ability to move from one place to another using various means. Thus, it can represent the way the user moves in the virtual environment. Typical types of locomotion include [3]:

- **Avatar movement** – represents the type of movement in which it is necessary to move the character with the help of a controller (for example, a joystick). This method is often used in various VR applications. The user can control the direction of movement and its speed with the controller, even if they are not moving.
- **Scripted movement** – represents when the camera in the virtual environment moves along a predetermined track. This movement is used, for example, in various virtual tours of buildings.
- **Driving** – in this case, the user controls the device, which moves even without constantly entering commands. This kind of motion often takes inertia and momentum into account. Unlike avatar movement, driving prevents you from stopping or changing direction immediately. Examples include driving school simulators and flight simulators.
- **Environmental movement** – this is a movement that occurs as a product of interacting with the environment, such as falling, diving, moving in an elevator, etc.
- **Teleportation** – a movement that leads to a sudden change in perspective. The user can suddenly move a great distance. The teleport can take place either in the entire range of the virtual environment or in predetermined locations.

Various types of locomotion may be suitable in various situations, however, it is important to take the comfort of a user into account. Many of these movement types are more likely to cause simulator sickness. The simulator sickness is caused by a discrepancy in the sensation of the vestibular apparatus and the eye. The brain then signals that the sensations do not match and concludes that the body is affected by a disease or toxin. Therefore, the brain can then cause headaches, nausea, disorientation

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or dizziness [4]. Using a VR headset can induce a type of motion sickness that may not involve actual movement.

The safest solution for locomotion in virtual environments is the utilization of teleportation. Instant movements are least likely to cause problems and are easier to implement. However, this may decrease the effectiveness of some virtual trainings. Fig 1. shows an example of the teleportation movement.

Fig. 1 Teleportation in VR (authors).

The player uses the pointer (white line with a marker at the end) to aim at the desired location and with a press of the set button will be instantly teleported to the selected location. Teleportation is currently the best option for locomotion in VR which offers solid movement and a smaller impact on the player's comfort.

3. NEW ALTERNATIVES: OMNIDIRECTIONAL VR TREADMILLS

One of the options that could be the best new alternative for the locomotive in a virtual world is the omnidirectional treadmill. Translating the exact real leg movement into the virtual world could significantly reduce the chance of simulator sickness while maintaining the high effectiveness of the virtual training. Fig. 2 shows an example of the omnidirectional VR treadmill.

Fig. 2 Omni-directional VR treadmill (authors).

The user walks on the platform as they would in real life while those movements are translated into the VR environment as precisely as possible. This has a big potential to increase the effectiveness of the virtual training. Especially those that require the exact leg movement and those that include long-distance walking (while holding an object). However, the question is if the current state of this technology is enough to be flawlessly implemented into VR education.

4. COMPARING THE TELEPORTATION AND OMNI-DIRECTIONAL VR TREADMILLS

A small study took place where a group of volunteers would try both ways of locomotion in a simple VR environment and then choose which one they preferred. In total, 15 people participated in the test. After they were questioned about which locomotion they found more suitable and comfortable. Fig. 3 shows the result of the test.

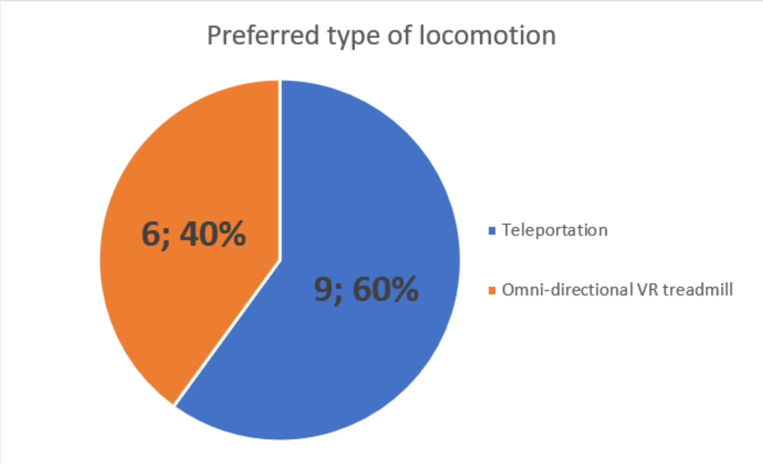

Fig. 3 Preferred type of locomation (authors).

60% of participants still preferred teleport as the better type of VR movement. All of them agreed on the same reasoning. The omnidirectional VR treadmill not always tracked their movements correctly which sometimes resulted in quick and sudden movements that are more likely to induce motion sickness. After a bit of practice, their control over the treadmill got better, however, they still preferred teleportation. On the other hand, they were also asked if they would give VR treadmill a try again if the controls were improved. All of them answered positively.

5. CONCLUSION

In conclusion, the usage of teleportation as the chosen type of locomotion still seems like the best compromise for most users. However, with the rapid development of new locomotion technologies for VR movement, this may not be the case in a few years. Omni-directional VR treadmill may soon be a staple in many virtual training applications as the best option for smooth a comfortable movement in a virtual environment.

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NEW APPROACHES IN THE DESIGN OF PRODUCTION AND LOGISTICS SYSTEMS IN THE CONTEXT OF SOCIO-TECHNICAL DEVELOPMENT

Abstract

The rapid advancements in technology have revolutionized the design of production and logistics systems, emphasizing the crucial role of the human factor within these socio-technical developments. By leveraging virtual and extended reality, novel approaches to education and training in areas such as assembly, maintenance, and quality control can be established. Moreover, these technologies offer opportunities to redefine the design principles of production and logistics systems, enabling innovative and efficient solutions.

Key words: production, logistics, new approaches, socio-technical development

1. SOCIO-TECHNICAL APPROACH DURING AGES

Manufacturing systems are constantly evolving in the areas of design, configuration, operation, and management in their ecosystem, which is characterized by new management methods, more advanced functions and new technologies and business models. Rapid technological progress and the development of innovative technologies allow to create new possibilities for operating production enterprises in which there are highly automated and interconnected production systems. It can be also stated that the future of production systems is mainly shaped by socio-technical development and business strategies. [1]

From the perspective of socio-technical development, the changes move the integration of human cyber systems (HCS) and cyber-physical systems (CPS) into an integrated concept of HCPS where human perception is introduced into cyber-physical systems. Subsequently, professional knowledge is included in control, analytical and decision-making processes. Supported by advances in the Internet of Things, the next generation of HCPS development is human-centric. To achieve human-centeredness, extended reality (XR) is a good visualization and interaction tool to connect people in the physical world with the digital world with an immersive experience, in which human-computer interaction (HCI) can be effectively enhanced with increased human involvement. Besides the integration of human-computer interaction (HCI), extended reality (XR) research is also a solid foundation for facilitating human-machine collaboration to complement each other in solving heterogeneous and multidimensional tasks and problems. [2]

At the end of the 20th century, the first step in the transition from classical design of production and logistics systems to modern digital design was simulation. The simulation contains an irreplaceable set of information technology (IT) tools and methods for the successful implementation of digital production. The simulation enables experimentation and validation of product, process and system design and configuration. It is used as a tool aimed at increasing production capacity, affecting costs, production time, quality, energy efficiency, safety, and productivity. [3]

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The next step is the use of digitization, which at the turn of the millennium moved simulations to a higher qualitative level. Simulation-based digital technologies are central to digital manufacturing solutions, as they enable experimentation and validation of different configurations of products, processes, and production systems. Digital manufacturing technologies are considered an essential set of supporting tools in the ongoing effort to reduce product development time and cost, as well as to expand product customization options. [3]

At the same time, digitisation played and plays a key role in the introduction of Industry 4.0 technologies. The digitalisation is a necessary condition for the effective use of other newly created technologies, including cyber-physical systems (CPS), Internet of Things (IoT), cloud computing, production network design, augmented and virtual reality (AR and VR), hybrid simulation and digital twins. [3]

Thanks to the rapid development of the Internet of Things (IoT), logistics and supply operations have been digitally transformed. Physical objects are interconnected to perform real-time monitoring and decision support through cyber-physical systems. In addition to machine-to-machine communication, humans play a critical role in IoT-enabled supply chain operations to monitor and configure IoT devices and interact with IoT systems for enhanced industrial intelligence. Extended reality (XR) technologies are used for immersive visualization to enhance the connection between human and cyber-physical systems. However, the role and development of extended reality (XR) in IoT-enabled supply chain scenarios is currently insufficiently described in the literature. [2]

With the advanced development of Internet of Things (IoT) technologies, today's logistics and supply chain management (LSCM) have been transformed to enable real-time control and monitoring. Through standardized IoT communication protocols, operational data (such as warehouse and transport environment conditions) can be visualized on IoT dashboards in real time. In other words, intelligent cyber systems were created to understand the physical and operational needs within cyber-physical systems (CPS). [2]

With the rapid arrival of the era of the integration of the Internet of Things into industry, software solutions are also being developed, the aim of which is to support the integration of IoT into the design and operation of production and logistics systems. This era is characterised by a large amount of data to be managed in real-time simulation models and by providing information that can quickly analyse different scenarios and provide decision support and system operation optimization. [3]

2. SUPPORT OF SOTWARE PLATFORMS

For this purpose, the major software companies are providing solutions that integrate the above-mentioned Industry 4.0 technologies into unified platforms, while also benefiting from machine learning techniques. For example, Watson is a unified platform that implements digital twin applications with operational simulation in extended reality. [3]

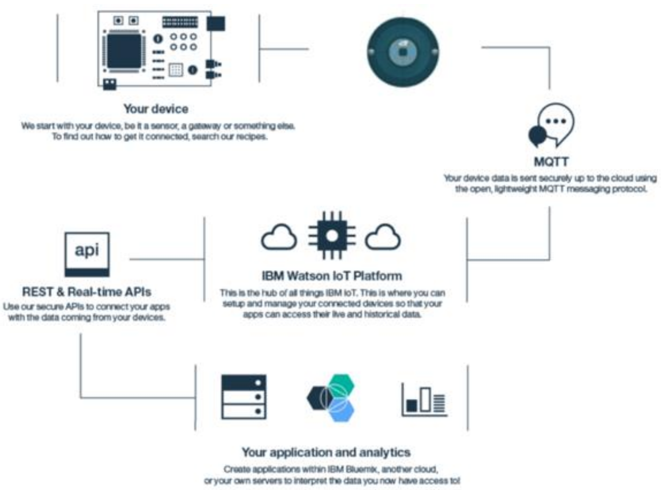

Fig. 1 Example of IBM Watson architecture
(https://docs.iotize.com/Technologies/IBMWatson/#introduction)

Another platform is Azure IoT Hub, which is gaining a lot of market share thanks to its integration with other digital solutions that have already achieved a high level of industrial integration, while also offering connections with advanced machine learning interfaces. [3]

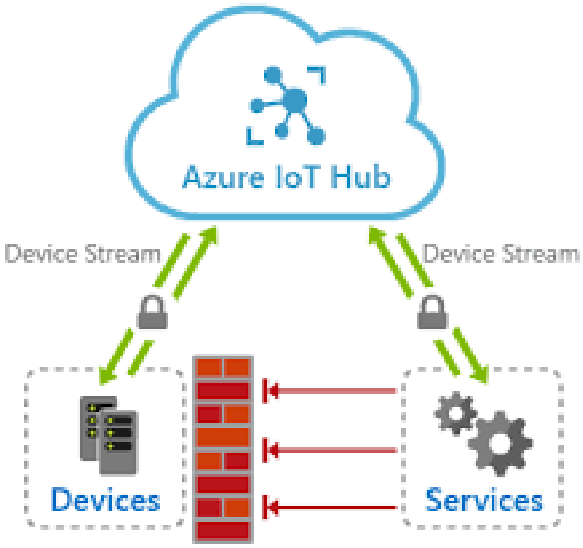

Fig. 2 Example of Azure IoT Hub for device streams (https://learn.microsoft.com/en-us/azure/iot-hub/iot-hub-device-streams-overview)

An example of an operating system is MindSphere, based on IoT, which offers open integration interfaces for development and connection with digital twin simulation software. [3]

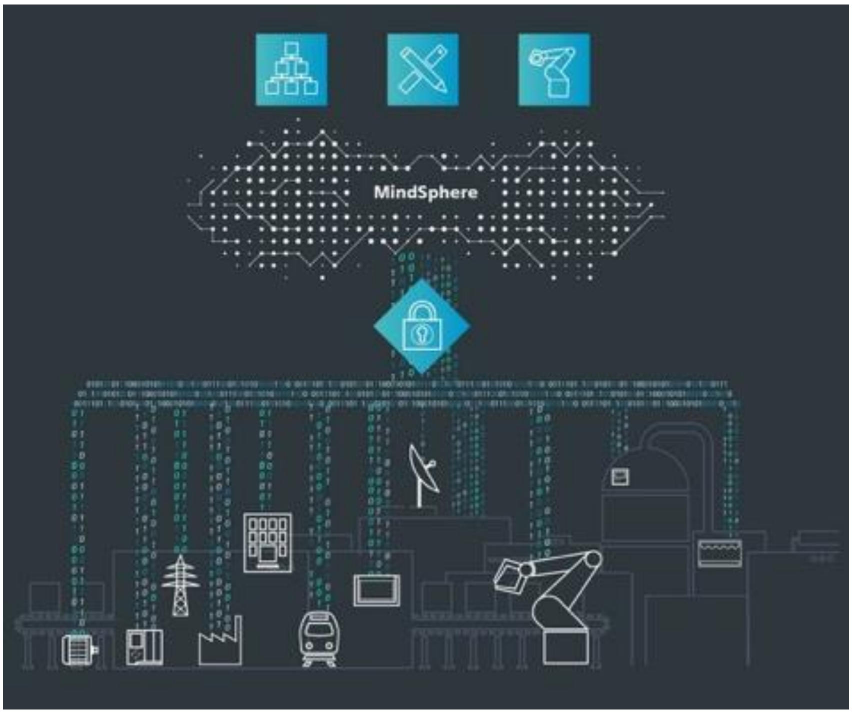

Fig. 3 Basis of OS MindSphere (Siemens) – connection with all industry branches (https://new.siemens.com/in/en/products/software/mindsphere.html)

The above-mentioned tools are not disconnected from their roots of core manufacturing simulations such as CAD, CAM or production simulation, but combine them with IoT data connectivity, cloud services and digital twin functions, expanding their capabilities for a new era. [3, 5]

2.1 The Ella Platform

In recent years, other platform providers have also emerged that did not provide simulation software in the past, but became directly active in new technologies (e.g. extended reality XR) and offered competing solutions (VecWorx). Consequently, more and more technologies will enable modelling and simulation, integration of data from different sources and adding them to more complex and realistic models (digital twins). (3) One example of such a company is EdgeCom, which deals with solutions for industry based on AR and VR. EdgeCom uses its own Ella platform to create solutions, which was originally developed to support the simulation and control of autonomous logistics tow tractors.

The Ella platform was created as an integrated software ecosystem on which multiple software applications are built. These applications focus on the design and analysis of internal logistics, monitoring, and simulation of automotive logistics assets and for virtual training. The platform enables separate solutions to share data about virtual worlds, objects, and process common information about the status of industrial operations in real time. This helps to provide users (customers) with uniquely integrated solutions with higher added value. C++, Python, OpenGL PhysX and other technologies were used to create the platform. Majority of the system logic is scripted in Python through the visual programming module. [4, 5]

Therefore, the Ella platform includes a complete set of tools for creating industrial applications and software aimed at:

- Simulation and emulation of logistics processes;
- Design of Industry 4.0 enterprises;
- Real-time data collection, analysis and evaluation;
- Control and navigation of logistics assets;
- Creation of specialized levels for training in virtual and extended reality;
- Server solutions without graphics support;
- 3D web interfaces. [4]

Fig.4 Ella platform – core, tools and products [4]

3. CONCLUSION

The design of production and logistics systems is currently mainly shaped by socio-technical development in which the human aspect is an important element. This means that people are part of a cyber-physical system in which they work with the latest technologies as a unified ecosystem.

The connection of new approaches in the design of production and logistics systems and the topic of my dissertation is the use of virtual and extended reality for training workers and creating educational programs enabling them able to use new technologies, but also use these technologies as a tool to facilitate their further education.

New technologies enable new forms of education and training (assembly, maintenance, quality), which we can use to prepare people to function in this ecosystem, but at the same time, these technologies also allow us to create new ways of designing production and logistics systems.

Examples of implemented trainings at EdgeCom, inc.:

- Delivery of a virtual training system for the production start of the RO 18 workplace in Lear Prešov company;
- Delivery of a virtual training system for driving training of ES vehicles;
- Delivery of a virtual training system for logistics at 3M Wrocław.

ACKNOWLEDGEMENT

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FUTURE DIRECTION OF GENERATIVE PRE-TRAINED TRANSFORMER (GPT) MODELS AND THEIR POTENCIAL USE IN EDUCATION AND MANUFACTURING

Abstract

This article provides an in-depth look at the future direction of Generative Pretraining Transformer (GPT) models and various ways they can be utilized in education and manufacturing. Utilizing the latest insights, it discusses the ability of GPT models to support personalized and student-oriented learning, as well as their potential in the field of industrial automation and robotics. The article also explores the role of AI "agents" capable of performing multiple tasks consecutively, and utilizing OpenAI's ChatGPT and GPT-4 as a basis.

Key words: Generative Pretraining Transformer, agents, queries

1. INTRODUCTION

Generative pre-trained transformers (GPT), such as GPT-4 created by OpenAI, are one of the latest advancements in the field of artificial intelligence and machine learning. These models use powerful algorithms to generate natural language, enabling the automatic generation of text based on provided information or instructions. They can be trained on a variety of tasks, enabling their use in various fields, including education, manufacturing, and software development [1]. An important aspect of GPT models is their ability to understand the context provided to them and generate accurate and relevant responses based on it. This can greatly impact the way we interact with technology, bringing new possibilities for automation and personalization of services. For instance, in education, GPT-4 can enable the development of personalized learning systems that could provide students with unique and tailored educational experiences [2]. GPT models also have significant potential in manufacturing and industry. Thanks to their ability to understand natural language and generate detailed and accurate instructions, they can be utilized to automate manufacturing processes and streamline work in the industry. In addition, models like GPT-4 can be used to develop new types of software and services, potentially opening new opportunities for innovation in the technology sector [3]. However, GPT-4, like its predecessors, is not without challenges. Their use requires a large amount of computational resources, and their results, though often accurate and relevant, are not always perfect. There are also questions about ethics and safety in the use of such models, particularly regarding their ability to generate content that could be misleading or inaccurate [4]. The following text aims to provide an overview of this new area of artificial intelligence as well as provide specific examples of real-world applications highlighting the potential these technologies offer in the context of education and manufacturing.

2. MATERIAL AND METHODS

The first GPT model was introduced to the market in June 2018 and since then OpenAI has successively released more powerful models, including GPT-2, GPT-3, and the latest model, GPT-4. These models are general language models that have learned to understand, generate, and respond to natural

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language through deep learning and massive training sets containing millions of web pages. They are used in a large number of applications, from content creation to conversational assistants.

2.1 GPT in education

In education, GPT models like GPT-4 can generate very detailed and accurate answers to questions, opening up fascinating possibilities for their use in learning environments. They can be used as tools for students to ask for information or help with problem-solving and can even serve as tutors, guiding students through complex concepts and aiding their learning. According to [2], the main advantage of GPT-4 is its ability to generate text that is more personal and tailored to the user's needs. For example, GPT-4 can be used to generate personalized conversations with students that can help them better understand concepts. Additionally, GPT-4 has the potential to be used as a teacher assistant, providing feedback on tasks and assisting students with their studies. GPT-4 also enables rapid and accurate content generation. This means that students can receive feedback on their assignments in real time, allowing them to make more effective corrections and improvements. Furthermore, GPT-4 can be used to generate content for online courses, enabling teachers to provide their students with engaging, interactive learning experiences. Another area where GPT-4 excels is in providing insight into student performance. By analyzing the text generated by the model, educators can better understand students' progress and identify areas where improvement is needed. An example is the use of the Duolingo Max software [5]. Duolingo Max incorporates GPT-4 technology to allow language learners to chat in a new language and get autogenerated explanations. GPT-4 does this by powering two new features for Duolingo Max: Explain My Answer and Roleplay. Sowtware allows users to have a conversation via text or speech with an AI chatbot powered by GPT-4. Roleplay feature allows users to have a conversation with a GPT-4 powered chatbot and then generates a report on the conversation see Fig 1.

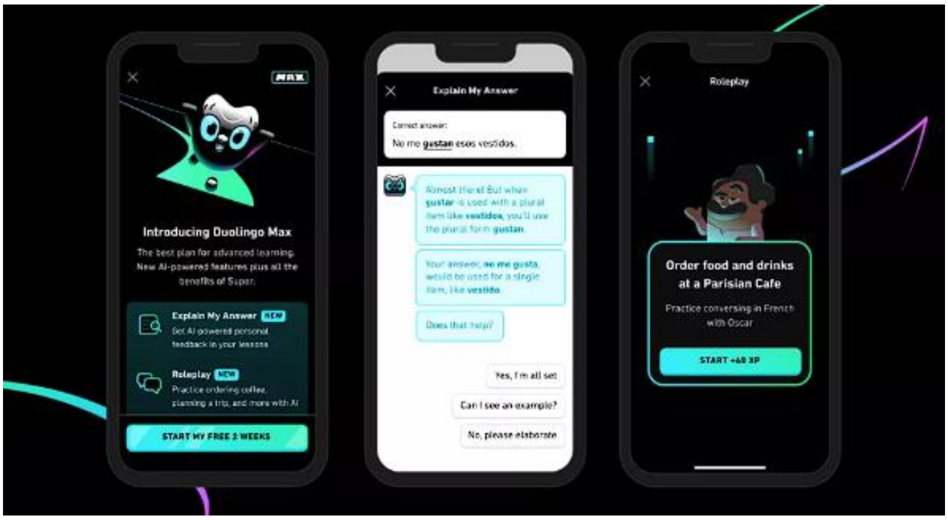

Fig.1 Visualization of the comunication process in Duolingo Max [5]

Moreover, models like GPT-4 can be used to develop new educational materials and to support teachers' creativity in preparing instruction. Despite these potential benefits, it is important to note that GPT models are not perfect. While they are capable of generating accurate and detailed responses, they are not immune to errors. Therefore, it is important for these models to be used as a supplement to traditional education, not as a replacement. While they have the potential to improve the educational process, it is important that they are always used in the context of appropriate pedagogical strategies and under the guidance of experienced educators [2].

2.2 GPT in manufacturing

GPT models can also bring significant benefits to industry and manufacturing, especially in the context of industrial automation and robotics. With their ability to interpret natural language and transform it into specific actions, these models can help automate various manufacturing processes, leading to more efficient production and cost reductions. An example is the company Groundlight, which has developed a platform based on the GPT model that allows programmers, regardless of their coding experience, to understand images programmatically using simple English instructions and a few lines of code [6]. This platform can be integrated into various applications, such as industrial automation, process monitoring, retail analysis, and robotics. An example might be a task when it is necessary to identify "Is a forklift blocking an aisle?" based on this query, the answer is then realized using current record recognition, see Fig. 2. This technology is already implemented in Austere Manufacturing in Washington State.

Fig.2 Visualization of the process of identifying the answer to the information query [6]

Another example outlining the future use of GPT is its application in robotics as demonstrated by a Microsoft study [7]. Robotics is one fascinating area where ChatGPT may be employed, where it can be used to translate natural language commands into executable codes for commanding robots. The benefit of adopting ChatGPT for robotic applications is that they may start with a modest amount of sample data to adjust the model for particular applications and make use of its language recognition and interaction capabilities as an interface see Fig. 3. Although ChatGPT's potential for robotic applications is getting attention, there is currently no proven approach for use in practice.

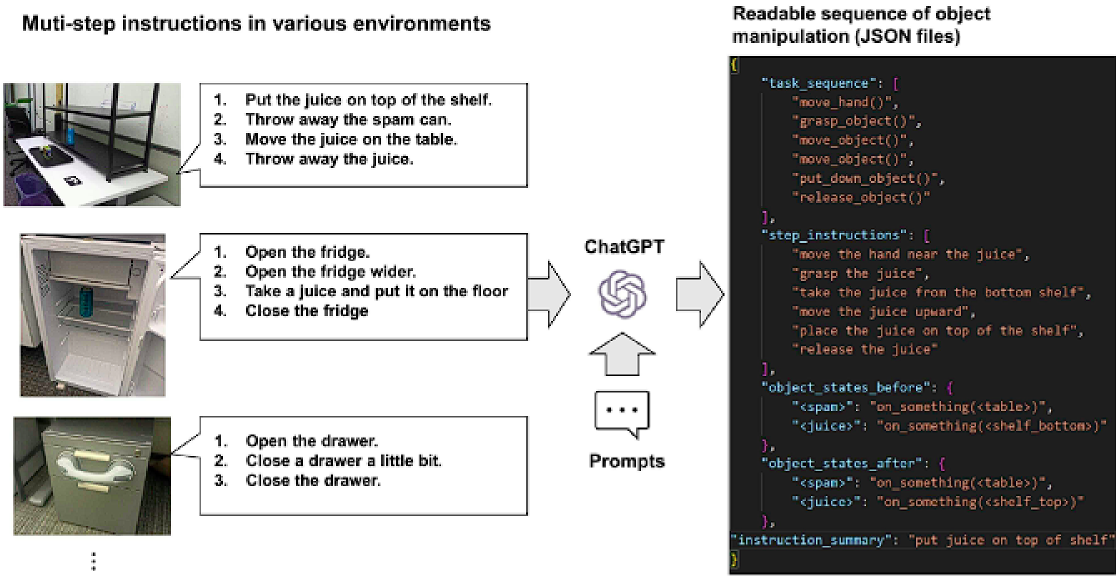

Fig.3 Visualization of the process of identifying the answer to the information query [7]

With proper design, GPT can also have another effect in the field, in the context of machine control using code commands [8]. It is common for an error to occur in the code, which a trained programmer has to search for, often having to do so on-site, during which time the machine may be switched off. The future solution could be a self-correcting" tool for artificial intelligence, which corrects errors in the code. When the user runs their Python program and it crashes, the created Wolverine tool will connect to the artificial intelligence GPT-4, which will fix the program and explain what was wrong.

The Wolverine code is available on GitHub, and the developer claims that this technique could be used in other programming languages as well.

2.3 GPT Agents

AI "agents" capable of executing multiple tasks in succession are another area where GPT models are proving advantageous in a production context. These agents are essentially autonomous systems that employ modern generative AI models for task automation. Most agents use OpenAI's ChatGPT and GPT-4 as their foundation, but several in-house agents also incorporate generative AI models for images and voice, creating surprising, though sometimes eerily realistic, performances. These agents leverage the power of GPT models for automating various processes. For instance, if you want an AI agent to create a plan to modernize your computer with a limited budget, you can assign tasks such as "find and compare the latest graphics cards based on a price under 500 dollars," then the same for a processor, RAM, and others. However, the benefits that GPT brings to manufacturing also carry their own challenges. While these models have the ability to automate and streamline many processes, they also introduce the potential for errors. Developers must remain vigilant in monitoring AI outputs and correcting any errors that may arise. Despite these challenges, GPT models are a massive boon for manufacturing and industry, and their usage in these fields will continue to increase in the coming years [9][10][11].

3. RESULTS AND CONCLUSION

The analysis presents various ways in which GPT models, such as GPT-4, could be employed in education and manufacturing. In the field of education, GPT-4 brings new possibilities for personalized and student-centered learning, including detailed question answering and tutoring. The showcased example, such as Duolingo Max, attests to this potential application. In the field of manufacturing and industry, GPT models have potential in industrial automation and robotics. Demonstrated examples, like the Groundlight platform and a study from Microsoft, testify to the potential of these models in automating manufacturing processes and in robotics. While this potential is still in the early stages of realization, it seems that GPT models have great potential to bring significant improvements to these areas. GPT models like GPT-4 represent a significant advance in the field of artificial intelligence and machine learning. Their ability to understand context and generate accurate and relevant responses based on this context brings new possibilities for their application in education and manufacturing. However, it is important to note that despite the immense potential of these models, challenges still exist. These include their computational resource requirements, potential errors in response generation, and ethical and security issues surrounding their use. These issues require further research and discussion. Despite these challenges, it is clear that GPT models have the potential to bring significant improvements to education and manufacturing. Their ability to support personalized learning and automate manufacturing processes suggests that they have great potential to become an important tool in these areas. Given how powerful and flexible these models are, it's likely that their usage will only increase in the future.

ACKNOWLEDGEMENT

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ORGANIZATION OF THE MANUFACTURING FLOW IN THE PRODUCTION SYSTEM

Abstract

The increasingly demanding conditions in which companies operate, and the factors that determine their activities, require changes in management processes. This publication presents the author's comprehensive methodology for implementing technological innovation in a manufacturing enterprise. Particular attention is paid to production flow organization. The presented concept determines the effectiveness of the production management process in a small batch production enterprise.

Key words: implement the innovation, evaluation and selection of the optimal solution, technical production preparation, production flow.

1. INTRODUCTION

In conditions of dynamically occurring changes in the economic and social environment, innovation, flexibility, and the ability to quickly adapt to new conditions become particularly important. The increasingly demanding operating conditions for businesses, as well as the factors determining their activities, require changes to be introduced in management processes. Achieving effective solutions in the shortest possible time in the production environment is necessary. The presented methodology allows for the creation and management of innovation concepts, followed by the evaluation and selection of optimal solution variants, and the development of technical preparation for production in terms of design, technology, and organization, as well as the improvement of production flow in the modified production system. The developed solution is an integrated approach that can ensure the long-term development and success of the organization. The variability and high dynamics of the environment necessitate continuous search, improvement, and dissemination of solutions.

2. DESIGN OF INNOVATION

Innovation encompasses a series of stages that begin with the development of a novel state tailored to meet a specific future requirement, followed by its conversion into a subsystem [1]. In the literature, many models depicting the innovation process can be found. These models vary in terms of the number of stages, complexity and scope [2]. There is a need to propose a comprehensive methodology that incorporates the stages of a novel business approach for the production of small-batch products. This approach should utilize new and effective tools while ensuring a relatively low project labor intensity. The proposed innovation project management model combines and develops new methodologies with traditional ones. The first step in the proposed approach is the application of the proceeding schemes described in the Blue Ocean Strategy concept [3, 4, 5]. The second approach integrated into the proposed innovation process model is the way in which the value proposition is created. The business model canvass and the value proposition canvass tool are combined, whereby the second tool is key to the first one [6, 7]. These two methodologies are proposed to be combined as complementary, and the effects of the concept can be complemented by another one - to be incorporated into the Quality Function Development (QFD) methodology [8, 9] which allows a consistent transfer of the designed customer requirements into the parameters of the designed product. The proposed approach takes into account the specificity of creating a concept for an innovative product in small-batch production under limited further design costs, while effectively addressing existing and projected requirements for creating new customer value.

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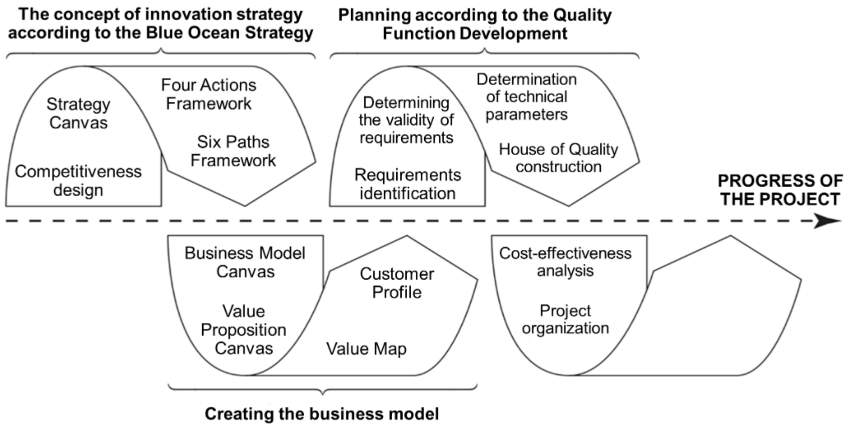

Fig. 1 Proposed model of management of the innovation project concept in small-batch production [10]

Innovation processes and their implementation are subject to a significant level of risk caused by the unpredictability of the results of implemented innovations or difficulties in forecasting. The level of detail required in the risk analysis depends on the specific application, data availability, and the needs of the organization [11]. The goal of multi-criteria decision-making is to determine the best solution by considering more than one criterion in the selection process [12]. To evaluate and select the optimal solution, an approach was developed using the classical method of evaluating solution options, complemented by a risk assessment using fuzzy logic (Fig. 2). Fuzzy logic is used to solve problems that are characterized by significant uncertainty and ambiguity [13]. The defined model includes technological, ergonomic, and economic criteria. A feature of the model is the inclusion of risk as one of the evaluation criteria in the selection of the optimal option.

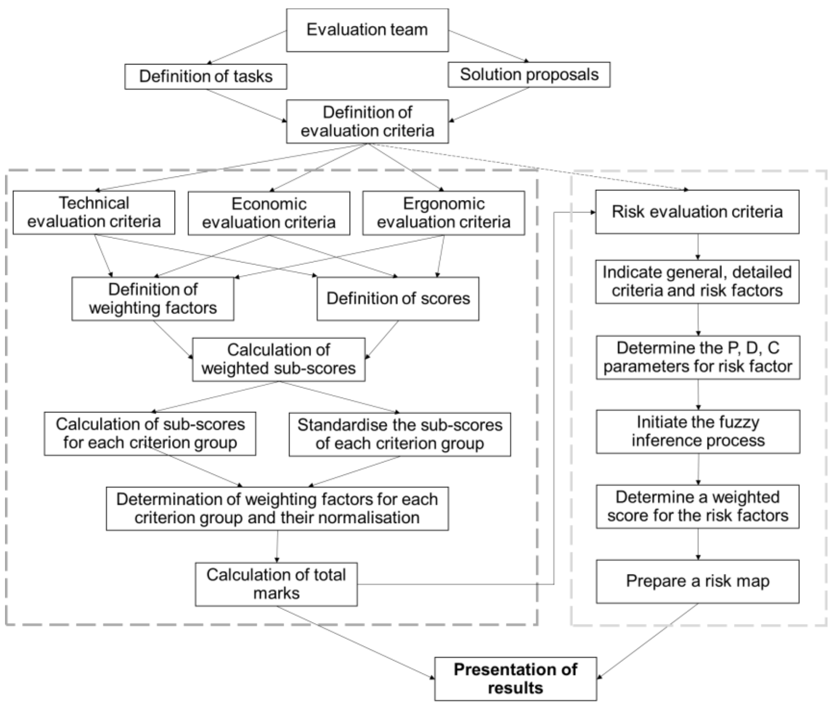

Fig. 2. Multi-criteria evaluation model enhanced by fuzzy logic-based risk assessment [14]

3. PRODUCTION FLOW ORGANISATION MODEL

Manufacturing systems should take into account the dynamics, as well as the impact of uncertainty and unexpected change [15]. Technical preparation of production is a set of activities that are used to determine the technical characteristics of products, as well as methods of their manufacture [16]. The design of production systems must provide effective solutions to satisfy demand [17]. When processes are properly controlled and improved, much better results are achieved, which are mainly manifested in financial savings, increased efficiency or a reduced workload for employees [18].

3.1 Object of the research

There are several main groups of band knives offered by the discussed company. These are raw band knives (unsharpened and untoothed), band knives sharpened on one side, band knives sharpened on both sides, single-toothed band knives, double toothed band knives (tab. 1.). The production process, depending on the type of band knife, includes various processes, among which are: measuring and cutting to size, welding, toothing, sharpening and setting. Not all products require all operations to be carried out. Band knives of all types with band width of 20 mm, thickness of 0.7 mm and length of 1500 mm were analyzed for each knife type.

Tab. 1 Production process for individual types of band knives, including lead times

BAND KNIFE 20 x 0,7mm							
Types of band knives	**Quantity [pcs]**	**Tooth pitch TPI**	**Cutting to size [s]**	**Welding [s]**	**Toothing [s]**	**Sharpening [s]**	**Setting [s]**
TYP_20Y – type of blade Y (one edge sharpened - angle 40°)	10	12.5	60	90	35	255	
TYP_21X – type of blade X (double-sided toothed)	30	2	60	90	170		
	20	4	60	90	100		
	15	6	60	90	65		
TYP_21R - type of blade R (double-sided toothed and setted)	5	2	60	90	170		140
	5	4	60	90	100		100
	5	6	60	90	65		55
TYP_22Y - type of blade Y (one edge sharpened - angle 20°)	10	12.5	60	90	35	255	
TYP_23Z - type of blade Z (two edges sharpened - angle 20°)	5	12.5	60	90	35	330	
	10	16	60	90	35	330	
	5	20	60	90	35	330	

The project of organizing the production flow emerged from the need to reorganize the production department in connection with the implementation of innovation, and consequently, the increasing dynamics of changes in the product range offered.

3.2 Course of the research

The technical preparation of a new production is supported by different methods, tools and realized in few phases. The model presented below shows such phases and the main processes of construction and technological production preparation for the technological innovation implementation.

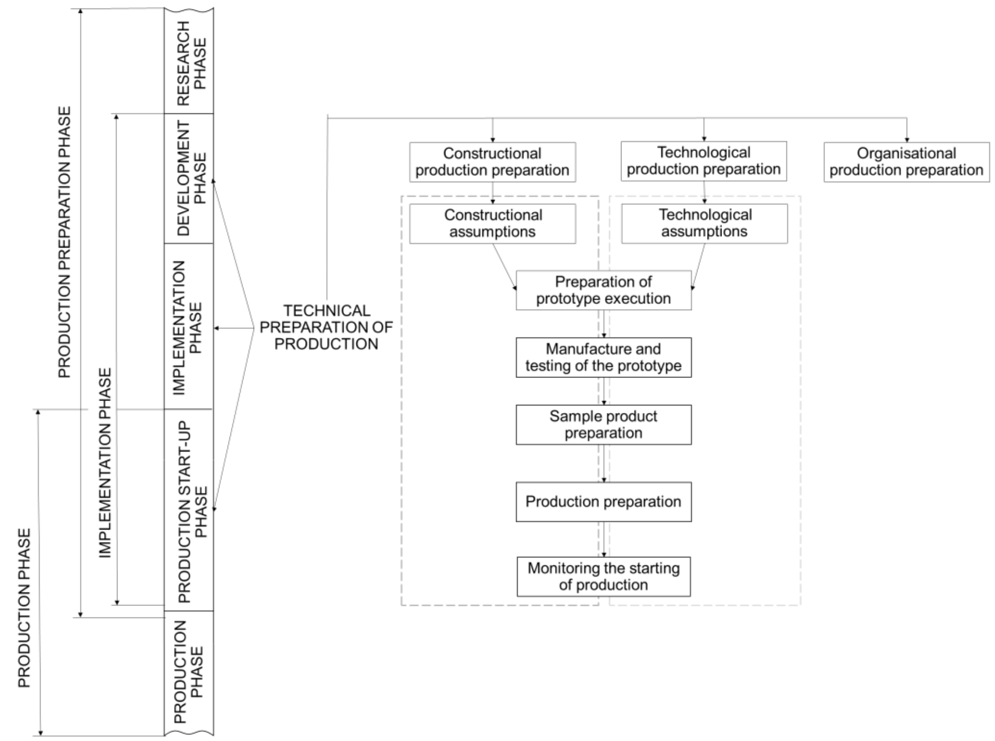

Fig. 3 Model of technical preparation of production [14]

This approach presents a proposal for the modification of a production flow improvement run in the Arena simulation programme (Fig.4.).

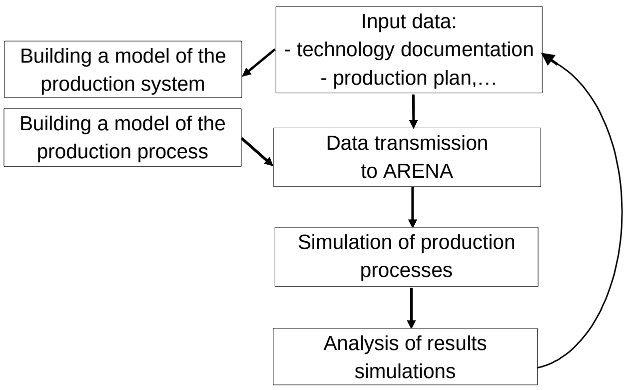

Fig. 4 The proposed modelling and simulation process flow [19]

Two runs were developed to simulate two different material flow scenarios. The simulations involved testing different groupings of products by changing the start times of production orders for different types of band knives. The most loaded station is the sharpening machine (81%), while the least loaded is the saw setting machine (2.5%). The analysis of the obtained reports showed that the production could be completed in one working day (two shifts) with the involvement of three operators. Comparing subsequent simulations revealed a reduction in production time for various types of knives, indicating increased process efficiency. Two variants of improvements were made, involving rearranging production plans for the first and second shifts. The simulations resulted in a 35% reduction in average manufacturing time and a 36% reduction in average waiting time. The biggest difference in average production time, compared to the base, is an almost 56% shorter average production time.

Average production time [hrs]	Variant I	Variant II
TYP_15X	4.84	2.68
TYP_16Y_2	5.88	4.13
TYP_16Y_2.5	2.27	1.58
TYP_16Z_2	7.93	5.86
TYP_16Z_2.5	4.63	3.25
TYP_17Y_10	4.74	3.36
TYP_17Y_12	2.71	2.02
TYP_17Y_6	2.56	1.86
TYP_19Y	6.03	4.27
TYP_19Z	9.94	7.66
TYP_20Y_12.5	4.85	3.48
TYP_21R_2	2.26	0.60
TYP_21R_4	2.29	0.92
TYP_21R_6	2.30	0.94
TYP_21X_2	6.51	3.86
TYP_21X_4	5.50	3.18
TYP_21X_6	0.45	0.45
WP_22Y_12.5	4.93	4.18
WP_23Z_12.5	2.98	3.60
WP_23Z_16	5.06	4.31
WP_23Z_20	3.15	3.78
WP_24R_10	4.89	2.27
WP_24R_4	4.86	2.24
WP_24R_6	3.86	1.81
WP_24R_8	2.49	1.15
WP_24X_10	3.80	1.75
WP_24X_4	2.36	1.01
WP_24X_6	3.75	1.71
WP_24X_8	5.57	2.47
Average time	4.26	2.77
Difference	35%	

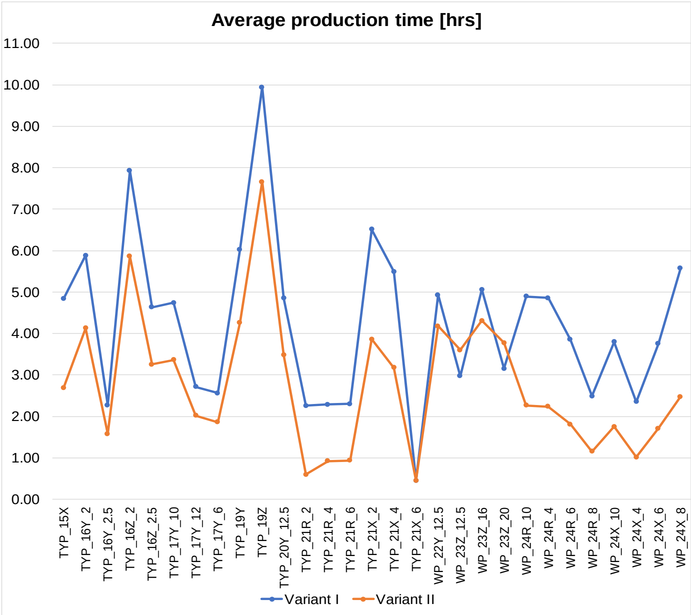

Fig. 5 Comparison of manufacturing times

Material flow simulation enables selective identification of disruptive factors in existing production systems to systematically improve them. Implementing material flow simulation at the right time allows for determining the correct trajectory before real production will start. It is worth monitoring the sharpening workstation because, in the case of inappropriate production organization, it can become a bottleneck in the system. One option is to introduce multi-station working, which is justified in this case. The sharpening technological nest consists of three stations ($m = 3$) with different processing times due to three different types of sharpening. The table presents the loading/unloading times labeled as a, processing times labeled as t, and transition times labeled as b.

Tab. 2 Calculation of sharpening operation times

	a	t	b	(a+t)	(a+b)
Station 1	30	130	20	160	50
Station 2	30	280	20	310	50
Station 3	30	205	20	235	50
				Cycle time: 310 seconds	Full cycle operator time Σ(ai + bi) = 150 seconds

From the calculations above, it follows that the cycle time is greater than the operator's time in a full cycle, so the cycle time is 310 seconds. Given the required operations and their respective execution times, we can determine the number of machines n' that can be serviced. This is expressed as the ratio of the cycle time to the operator's time per machine:

$$n' = \frac{(a+t)}{(a+b)} \tag{1}$$

The number of machines operated by the operator is n' = 2.07, so from this it follows that $m > n'$, i.e. the machines will be idle. The next step is to determine the machine idle times I_m for one cycle T_c and operator I_o.

$$T_c = \begin{cases} (a+t) \\ m(a+b) \end{cases} kiedy \begin{matrix} m \le n' \ (bezczynność\ operatora) \\ m > n' \ (bezczynność\ maszyn) \end{matrix} \tag{2}$$

$$I_m = \begin{cases} 0 \\ T_c - (a+t) \end{cases} kiedy \begin{matrix} m \le n' \\ m > n' \end{matrix} \tag{3}$$

$$I_o = \begin{cases} T_c - m(a+b) \\ 0 \end{cases} kiedy \begin{matrix} m \leq n' \\ m > n' \end{matrix} \tag{4}$$

The cycle time is T_c = 450 seconds, idle time for machines I_m = 140 seconds and operator I_o = 0. The number of machines serviced by the operator has been determined to minimize costs, assuming that the operator's hourly cost (C_o) is 25 EUR and the machine's hourly cost (C_m) is 35 EUR.

$$TC(m) = \begin{cases} \frac{(C_o + mC_m)(a+t)}{m} \\ (C_o + mC_m)(a+b) \end{cases} kiedy \begin{matrix} m \leq n' \\ m > n' \end{matrix} \tag{5}$$

$$\phi = \frac{TC(n)}{TC(n+1)} = \frac{(C_o + nC_m)(a+t)}{n[Co+(n+1)Cm](a+b)} = \left(\frac{\varepsilon+n}{\varepsilon+n+1}\right)\left(\frac{n\prime}{n}\right) \tag{6}$$

If ϕ < 1 then $TC(n)$< $TC(n+1)$ then n machines should be assigned per operator, and if ϕ > 1 then $TC(n)$ > $TC(n+1)$ then n+1 machines should be assigned per operator, assuming n is an integer part of n'.
As a result of calculations ε = 0.71 and ϕ = 0.76, it was deduced that two machines should be operated by an operator to minimise costs. This will allow for smoother operation, elimination of waste and an increase in added value.

4. DISCUTION RESULTS AND DISCUSSION

The proposed approach utilizes the Business Model Canvas (BMC) and techniques for creating a business model to develop the concept of an innovative product. Additionally, the Quality Function Deployment (QFD) matrix can be used to facilitate the transformation of market requirements into technical parameters and a set of conditions to be met at each stage of product development. The use of multi-criteria evaluation of alternatives, a key component of the assessment and selection phase, enables the identification of a compromise solution that is advantageous in terms of technical, economic, and ergonomic criteria, forming the basis for optimal decision-making. A distinctive feature of the created model is the consideration of risk as one of the evaluation criteria for selecting the optimal variant, influencing actions related to the rationalization of production systems.
Technical production preparation and production flow simulations allow for early problem identification and reveal potential for optimization. The benefits of optimizing production flow include complete visibility of the entire process, cost savings, improved operational efficiency, and increased productivity. The production process has been comprehensively optimized.
Future research should focus on exploring ways to integrate new technologies into existing production processes. Analyzing the impact of introducing innovative solutions on the flow of production and identifying best practices for technology integration can contribute to effective innovation implementation. Additionally, future studies should concentrate on developing methods and tools that enable rapid reconfiguration and adjustment of production processes to maintain flexibility and adaptability to changes.

5. CONCLUSIONS

The conclusions of the conducted research provide practical guidelines for contemporary companies. The proposed methodology for managing the concept of an innovation strategy allows for more efficient and effective project management. The improved approach will contribute to greater efficiency in delivering innovative solutions and enable the successful implementation of future projects. The results of these projects serve as recommendations for organizations facing challenges in creating and implementing technological innovations.

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REDUCING INTERNAL LOGISTICS COSTS BY IMPLEMENTING AGVs

Abstract

The company's internal logistics is one of the specific areas that we should improve and optimize. By improving internal logistics, it is possible to effectively reduce its costs. The paper deals with the design of automated guided vehicles (AGVs) to support internal logistics in a specific organization. The proposal includes a description of a specific company, selection and description of suitable AGVs, use of trucks, time calculations and subsequent calculation of the number of trucks needed for internal material needs in the production company. At the end of the papier, the benefits, return on investment and expected cost reduction are described.

Key words: internal logistics; production company; automated guided vehicles (AGV); production line

1. INTRODUCTION

Internal logistics (production logistics) covers the planning, implementation, control and efficient flow and storage of material, semi-finished products and finished products in production processes and the production environment. [1]

Therefore, intra-company supply must be sufficiently flexible and at the same time properly planned, as well as for the purpose of preventing unexpected downtime and unwanted stops. Production logistics is one of the active factors involved in increasing the overall production performance of the plant, as intralogistics has a direct impact on the optimization of the use of resources, the reduction of production product time, optimization of production stocks, utilization of warehouses and increasing the quality of production. [2,3]

With the increase in the overall complexity of production processes by the increase in the amount of equipment, workers as well as the quantity of input material and semi-finished products in the company, the management of internal logistics systems becomes more and more demanding [4,5]. The constant expansion of the variability of manufactured products, the pressure to reduce production times and optimize operating costs forces companies to modernize established intralogistics processes in order to be able to respond more flexibly to changes in both the production environment and the market. [6,7]

Although the autonomous driving of a motor vehicle in traffic is quite problematic, autonomous vehicles have so far found their place in factories and warehouses as "logistics trains". Automated guided vehicles (AGVs) are one of the ways to speed up and make logistics processes more efficient. This post will cover how AGVs are guided and how safety is achieved. [8,9,10]

The method of production is changing. There are more robotic workplaces, human-robot cooperation, inventory is being reduced and just-in-time production is taking place. Here is a question of intralogistics and autonomous trucks arises. In factories where people are present, this also means high demands on safety and collision prevention. Truck anti-collision systems are also important in terms of protecting

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property and preventing collisions with other vehicles. The future lies in the use of collaborative robots moving on autonomous carts, while they can move from one workplace to another. Autonomous driving must have accurate navigation, inform about its position and be safe for people and property. [11, 12, 13]

For internal logistics to be effective, it is necessary to introduce new and automated technologies to improve the logistics flow [14]. Many companies struggle to find and implement a suitable automated solution with satisfactory ROI. AGVs offer a simple solution to improve internal logistics. Secondly, this solution must be chosen appropriately for a specific company and must comply with the set logistics strategy. [15, 16]

2. CASE STUDY

The case study deals with the proposal to introduce AGVs for the needs of internal logistics in a manufacturing company. The manufacturing company in the case study manufactures platforms, ladders, mobile platforms, mobile scaffolding towers and fixed ladders from aluminium. It operates internationally with its headquarters in Germany and three production facilities in Europe. The products combine many advantages of aluminium, such as high stability with low weight, corrosion resistance and flexibility of use. The company exports its products to more than 60 countries. The manufacturing plant on which the case study is oriented has fourteen production lines, a warehouse for small parts, a warehouse for long profiles and a warehouse for finished products.

1.1 Selection of AGVs

The implementation of new technology in internal logistics was a proposal to introduce AGVs (Fig. 1). The selected model is designed to automate the transport of pallets and heavy loads in various industries. With a maximum possible load of 500 kg and a storage area of 1350 x 920 mm, it is a large, powerful, and collaborative mobile robot.

When loading AGVs, there is no need to adjust the layout of the equipment. This technology is currently being replaced by navigation software.

The software works on the compatibility of the truck with DGN format files or point clouds that are the product of laser scanning, according to which the algorithm evaluates the best path.

Fig. 1 A sample of the tested AGV (Štaffenová, 2021)

This cart is resistant to material dropped from a height directly onto the cart, and functionality is not affected even by going over ramps and slight surface imperfections.

The permissible temperature for the correct operation of the truck while running should be between 5°C and 40°C. The trolley can be stored in a temperature range from -10°C to 60°C. The humidity of the truck's working environment should range from 10% to 95% without condensation. The trolley can pass through water on the floor that is no more than 4 mm deep. The truck has implemented five safety measures. The truck stops immediately if the safety measures are activated.

The trolley has an implemented 360° visual protections around the robot in the number of two pieces. It also has two 3D cameras that can capture objects 1700 mm high and 950 mm away from the cart. The minimum distance to objects from the cart is 250 mm. The cart has eight proximity sensors.
The cart has a speaker, four light signals on each side and signal lights (two on each corner).

AGVs are designed for two work shifts lasting 8 hours. It means 16 hours of work in one day. The trucks will work five working days a week. Maintenance must be carried out every six months, through the four maintenance hatches on the trolley (each on one side).

1.2 Use of AGVs in the production hall

The trucks will move material from the small parts warehouse to four lines. The route from the small parts warehouse will have to be made by an AVGs 64 times a day to cover the consumption of material needed in production on the given line.

This means that they will have to carry out four transports per hour to line X. According to the proposed route for AGVs, the distance is 108 m from the warehouse of small parts to line X. The same number of transports per day and per hour will also have to be carried out when moving material from of the small parts warehouse to line Y and line Z. The length of the AGV transport route from the small parts warehouse to line Y is 80 m, and the length of the AGV transport route from the small parts warehouse to line Z is 40 m. For the quantitative needs of line S, it will be necessary to transport material 48 times per day, which represents the implementation of material transport using an AGV three times per hour. The length of the transport route from the warehouse of small parts for the AGV is 74 m.

1.3 Time recalculation

The AGV will move at a speed of 1 $m.s^{-1}$, which translates to 3.6 $km.h^{-1}$. This value is set by the manufacturer. The cart has specific times for performing certain tasks. The time required to place the cart at the pick-up or delivery station is 30 seconds. The time required for loading and unloading the material is set at 130 s. The total handling time is therefore 320 s. Table 1 shows the time calculation for individual collection points of AGV trucks. The table contains data for transports during one hour. This means that it will be necessary to use 28.53 minutes out of one hour to move the material by AGV to line X. For Y line material it will be 26.67 minutes out of one hour, for Z line 24 minutes out of one hour and for S line it will be 19.70 minutes out of one hour.

Tab. 1 Time recalculation (own processing).

Collection point (line)	**X**	**Y**	**Z**	**S**
Number of transports per hour	4.00	4.00	4.00	3.00
Distance [m]	108.00	80.00	40.00	74.00
Driving time [s]	108.00	80.0	40.00	74.00
Driving time [min]	7.20	5.33	2.67	3.70
Handling time [s]	320.00	320.00	320.00	320.00
Handling time [min]	21.33	21.33	21.33	16.00
Total time [min]	28.53	26.67	24.00	19.70

3. RESULTS

To calculate the number of necessary trucks, it is necessary to complete the data. We will supplement the data from Table 2. The total number of transports that the truck must make in one hour to ensure the need for input material to the line is 15. The total driving time is 18.9 minutes in one hour. The total handling time during one hour is 80 minutes. The time spent by one cart blocked by an item was set at 3.8 minutes. Blocking with an item means, for example, passing through a door, when the cart must slow down.

The total utilization of the AGV truck, considering all aspects, is 102.7 minutes in one hour. The efficiency of the truck is 90%, so this time is adjusted to 114.1 minutes within one hour. This time also includes the time to charge one cart, which is 22.82 minutes within one hour.

Overall, it follows from these data that it is necessary to implement exactly 1.90 units of carts that would be active and exactly 0.38 units of carts inactive due to charging. After rounding, it is necessary to introduce two carts that will be active and one that will be inactive due to charging.

In total, to meet the needs of the supplied material, it is necessary to procure three trucks with a total efficiency of 76%. The data are listed in Table 2.

Tab. 2 Data for calculating the number of AGV trucks needed (own processing).

Activity	**Value**	**Units**
Transport	15.0	times per hour
Driving time	18.9	$min*h^{-1}$
Handling time	80.0	$min*h^{-1}$
Block time	3.8	$min*h^{-1}$
Use of AGVs	102.7	$min*h^{-1}$
AGV efficiency	114.1	$min*h^{-1}$
AGV charging	22.82	$min*h^{-1}$
Active AGV	1.90	pcs
Inactive AGV	0.38	pcs
Number of AGVs needed	3.00	pcs

The expected price of one cart is 70 000 €. The expected price represents the price provided by the supplier of AGVs to the company through a quotation. This price represents the cost of the device, including the docking station, software and hardware, shipping, installation and training of workers.

For example, for line X, the cost of a warehouseman is 27 000 € per year and the cost of a forklift truck is 3 600 €. Information on the amount of costs was obtained from data from past periods, specifically for 2020 and 2021. The savings on line X represent the replacement of two warehouse workers and two forklift trucks with one AGV truck.
The return on investment for line X is approximately 1.2 years.

$$ROI = \frac{The\ price\ of\ the\ investment}{Savings} = \frac{70\ 000\ €}{2*27\ 000\ €+2*3\ 600\ €} = 1.18\ years \tag{1}$$

The total savings after implementing three trucks represent the savings of five warehouse workers and four forklift trucks.

$$ROI = \frac{The\ total\ price\ of\ the\ investment}{Total\ savings} = \frac{3*70\ 000\ €}{5*27\ 000\ €+4*3\ 600\ €} = 1.454\ years \tag{2}$$

The total return on the entire investment in the implementation of AGV trucks is approximately 1.5 years.

4. CONCLUSIONS

After the introduction of the AGVs system, we will achieve, with a two-shift operation, a reduction in costs per warehouse worker in the amount of 39 000 € per year. The costs of renting forklifts will also be reduced. The cost of one cart can be reduced by up to 3 600 € per year.

Continually with the implementation of AGV trucks, the Poka-yoke system will also be introduced, i.e. the provision of error prevention. There will be no chance of mixing or exchanging small parts during shipping. When the parts are delivered, it is possible to order the delivery of other parts to a specific line using the software and the control panel on the truck.

By preventing the creation of breaks, an increase in production efficiency is achieved by using AGV trucks, which can transport a higher volume. The only downtime with AGV trucks is the time required to charge the truck. Another option for making the use of AGV trucks more efficient is the merging and optimization of transport routes in the future according to the current production needs, or by adding service lines.

The internal logistics support solution using AGVs technology is efficient, elegant with a high return on investment. After the appropriate selection of the lines to be supplied with trucks, the selection of the right truck and with the correct calculations of the number of necessary AGVs, the company will support the overall logistics strategy and create a new possibility for further optimization of internal logistics. After the introduction of AGVs, one should not forget the next steps and the direction to use other tools, such as fully automated warehouses and automatic supply planning, which, together with the implementation of AGVs, create opportunities for businesses to use their full potential and achieve set goals.

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CREATION OF A MOBILE LOCALIZATION RTLS NETWORK IN LABORATORY PREMISES

Abstract

This paper deals with the creation of a mobile RTLS localization network in laboratory conditions at the Department of Industrial and Digital Engineering. Real-time localization (RTLS) is an important aspect in many fields, including industry, healthcare and logistics. The goal of this paper was to design and implement an RTLS network that enables accurate tracking of the movement of mobile devices and people in laboratory spaces.

To achieve this goal, we used UWB RTLS and radio frequency-based sensor technology. We created the network architecture and designed an efficient algorithm for locating devices and people moving around the laboratory. The implementation took place in a laboratory environment, where we tested and evaluated the performance and accuracy of the system.).

Key words: RTLS system, UWB, laboratory

1. INTRODUCTION

In recent years, mobile tracking systems have become a key tool for accurately tracking and locating mobile devices in various areas. One important application is real-time localization (RTLS) in laboratory spaces. This technology offers the possibility of tracking the location and movement of mobile devices with high accuracy, which is essential for effective management and optimization of processes in a laboratory environment. Currently, there are many technologies and approaches to localization, including WiFi, Bluetooth, ultra-wideband (UWB), and radio frequencies that can be used to implement an RTLS network. In this article, we will focus on the combination of UWB RTLS and radio frequency sensors, which has proven to be a powerful and accurate method of localization in laboratory spaces. RTLS localization systems (Real-Time Location Systems) represent an important tool for accurate tracking and localization of objects or people in real time. In recent years, these systems have become increasingly widespread in various industries, including industry, logistics, healthcare, and scientific research.

First of all, we will focus on the design of the network architecture and the selection of suitable components for the implementation of the RTLS system in a laboratory environment. Next, we will deal with the development of an effective localization algorithm that will be able to accurately track the movement of mobile devices in space. The implementation and testing of the system will take place in real laboratory conditions, where we will evaluate the performance and accuracy of our created RTLS system.

2. CREATION OF A MOBILE LOCALIZATION RTLS NETWORK

For the RTLS system to be used anywhere, it is necessary to measure the space as accurately as possible so that its subsequent floor plan can be used in the RTLS Manager as a basis for data visualization. We measured room 206 in building PK6 using a laser meter. Next, we drew the position of the tables and their dimensions in the sketch, as each table will have its own zone.

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After measuring all the important data, we created a floor plan in the AutoCAD Architecture program according to the template. The resulting floor plan was saved in .jpg format so that it could be imported into RTLS Manager.
After measuring the room and creating its floor plan, it was necessary to prepare the hardware that will be used during our measurement. The following components are required to connect the anchors to the system:

- Ethernet cable,
- Switch with active PoE,
- Computer.

The next step was putting the tag into operation. In our work, we used the Leonardo Asset type. All you need to put it into operation is to insert the battery and reset the tag. Subsequently, the anchors already detect the tag if it is located in the area they are scanning. The Leonardo Asset tag uses a CR2477 type battery. The bottom left image shows the Leonardo Asset tag completely disassembled together with the battery.

Fig.1. Tag and its components

2.1 Anchor settings

Setting the anchors consists of two parts. The software setting is preceded by the hardware setting and this includes their placement. In addition to the layout, which will ensure successful coverage of the area with the signal, other factors that can affect their proper functionality must also be taken into account. The conditions that must be met include the following:

- The distance between the anchors must not exceed 25 m (in our case this will not happen, as we are in a small room)
- The height difference between the tag and the anchor should not exceed 5 m (in our case, this is not a risk, as we do not have such high ceilings)
- The anchors should be placed at the same distance from the ground (in our laboratory, we placed the diodes on the anchors at a height of 2.20 m)
- The anchors should form a square or rectangular structure
- Ensure an optimal Line of Sight - without obstacles (we adapted the height of the anchors due to the support beam)

Fig.2. Anchors in laboratory 206

2.2 Tags settings

Setting up tags is a much simpler process than setting up anchors. As mentioned earlier, you only need to insert a battery into the tag and the system will automatically register it. For better orientation among so many tags, we have named them according to their physical name, which is stuck on the packaging.

#	Tag Mac	Tag Alias editable	Tag uuid editable	Status	Received blinks	Platform	HW	FW	Battery	Refresh Interval [ms]	TX Power	Sleep Mode	Sleep Threshold
1	23035e7210da	RTLS_TAG_0001	a9e17016-b29c-11ed-9d3e-23035e7210c	3/16/2023, 09:39:58	923	Leonardo Asset	1.3	3.125	88% [3.02V]	1000	[47474141]	Immediate Sleep	Low
2	23035e7203d1	RTLS_TAG_0003	2f5f46d0-c339-11ed-b3f0-23035e7203d1	3/16/2023, 09:27:52	398	Leonardo Asset	1.3	3.125	100% [3.13V	1000	[47474141]	Immediate Sleep	Low
3	23035e71e938	RTLS_TAG_0009	a9e735a0-b29c-11ed-8fb3-23035e71e93	3/16/2023, 09:28:31	239	Leonardo Asset	N/A	N/A	91% [3.05V]	0		N/A	N/A
4	23035e720a63	RTLS_TAG_0005	56f8cafe-c334-11ed-b163-23035e720a6	3/16/2023, 09:28:12	315	Leonardo Asset	N/A	N/A	100% [3.13V	0		N/A	N/A
5	23035e720459	RTLS_TAG_0004	b874c030-c334-11ed-aaf8-23035e72045	3/16/2023, 09:27:53	387	Leonardo Asset	1.3	3.125	100% [3.13V	1000	[47474141]	Immediate Sleep	Low
6	23035e720e39	RTLS_TAG_0007	af8c8cc6-c336-11ed-a38c-23035e720e3	3/16/2023, 09:28:04	407	Leonardo Asset	1.3	3.125	100% [3.13V	1000	[47474141]	Immediate Sleep	Low
7	23035e720d9d	RTLS_TAG_0002	d16de95a-b299-11ed-92b3-23035e720d	3/16/2023, 09:28:46	495	Leonardo Asset	1.3	3.125	88% [3.02V]	1000	[47474141]	Immediate Sleep	Low
8	23035e71c60a	RTLS_TAG_0010	296326e4-c338-11ed-a2ae-23035e71c60	3/16/2023, 09:28:20	307	Leonardo Asset	N/A	N/A	100% [3.13V	0		N/A	N/A
9	23035e71e407	RTLS_TAG_0008	bdce890c-c3cb-11ed-8d0a-23035e71e40	3/16/2023, 09:28:30	659	N/A	N/A	N/A	N/A	0		N/A	N/A
10	23035e720f47	RTLS_TAG_0006	62f0c56c-c3cc-11ed-96aa-23035e720f47	3/16/2023, 09:28:13	759	Leonardo Asset	1.3	3.125	100% [3.13V	1000	[47474141]	Immediate Sleep	Low

Fig.3. Changing the name of tags

2.3 Preparation and setup of the software part of the RTLS system

To use the RTLS Manager, which is the basic module for starting the entire RTLS system, it is necessary to install the so-called of a virtual machine that "starts" the instance necessary for using the RTLS Manager. This virtual machine can be downloaded from the Sewio site, which will then run in VirtualBox. Before we get to the RTLS Manager, we need to log in with our VirtualBox credentials. Subsequently, it will be possible to open the RTLS Manager in the browser, where we will perform other settings.

```
sewiortls login: sewiortls
Password:
Last login: Thu Mar  9 12:42:15 UTC 2023 on tty1
Welcome to Ubuntu 18.04.4 LTS (GNU/Linux 4.15.0-109-generic x86_64)

 * Documentation:  https://help.ubuntu.com
 * Management:     https://landscape.canonical.com
 * Support:        https://ubuntu.com/advantage

  System information as of Thu Mar  9 12:51:58 UTC 2023

  System load:  1.35               Processes:             126
  Usage of /:   36.4% of 19.56GB   Users logged in:       0
  Memory usage: 37%                IP address for enp0s3: 192.168.225.2
  Swap usage:   0%


 * Canonical Livepatch is available for installation.
   - Reduce system reboots and improve kernel security. Activate at:
     https://ubuntu.com/livepatch

0 packages can be updated.
0 updates are security updates.

Failed to connect to https://changelogs.ubuntu.com/meta-release-lts. Check your Internet connection
or proxy settings


Welcome to RTLS Studio Server
Status of initial configuration: OK
sewiortls@sewiortls:~$
```

Fig.4. Logging into VirtualBox

The home page of RTLS Manager is accessed using the IP address that we specified in the settings and entered in the browser. We logged in again using the login data and then it was possible to start setting up the system.

The first step is to set the anchors and find the so-called master (main) anchor. The main anchor is determined according to the best signal strength, which is usually detected by the system itself. Another no less important task is to determine the stability of the anchors in relation to the main anchor. We can check this with the help of a graph. The stability values should be lower than 2.0, if this value is exceeded, it is necessary to change the orientation of the anchors by turning them either more into the room or into the floor. We managed to achieve stability below 2.0 on the first try, with subtle adjustments we reduced stability below 1.0. The image below shows the achieved stability of our anchors. For a better overview and in the event of a problem, we have named the anchors according to their location within the floor plan.

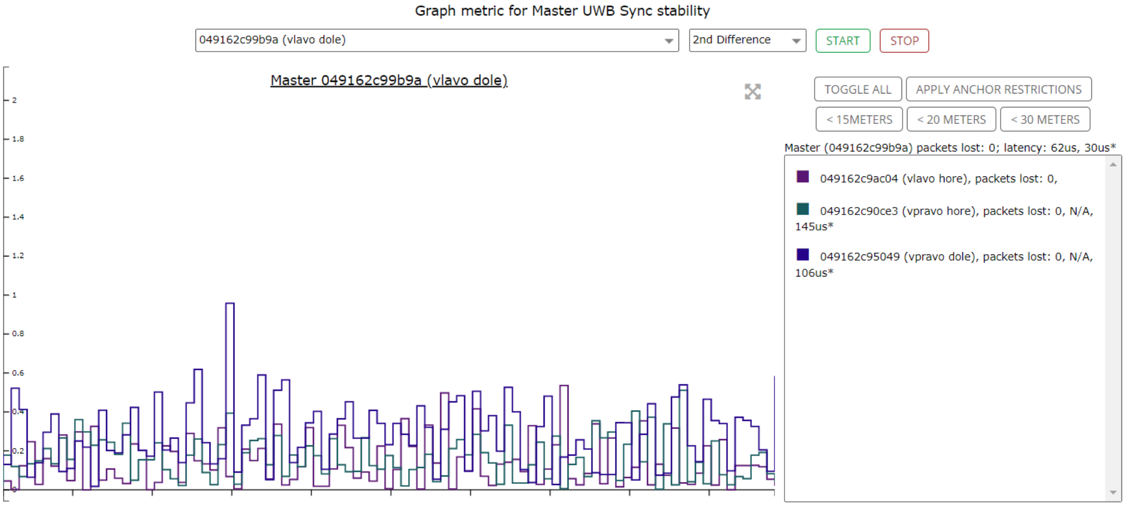

Fig.5. Setting the main anchor and checking stability

To visualize this contribution, it was necessary to create a floor plan of the room where we will perform the measurement. After creating this floor plan, it is necessary to upload it to the Sewio portal in the Sensmap Visualization section. In the Explore → Buildings section, click on the house icon with the plus sign. Uploading a building to Sensmap Visualization is intuitive on the whole. It is only necessary to name the building, upload its plan (floor plan), which we will also name. After uploading, it is necessary to adjust the scale of our room. This is done by clicking the second icon from the left (in the red circle). In our case, we chose the width of the room (x-axis) as the scale, after measuring it in Sensmap, we wrote down its actual dimensions so that the system knows how to place the anchors.

Anchors can also be placed manually in the plan, but it is easier to use the auto-deploy function, which places the anchors based on their distance into a rectangle that we place in the plan based on our needs.

The following image shows the already added floor plan in RTLS Manager.

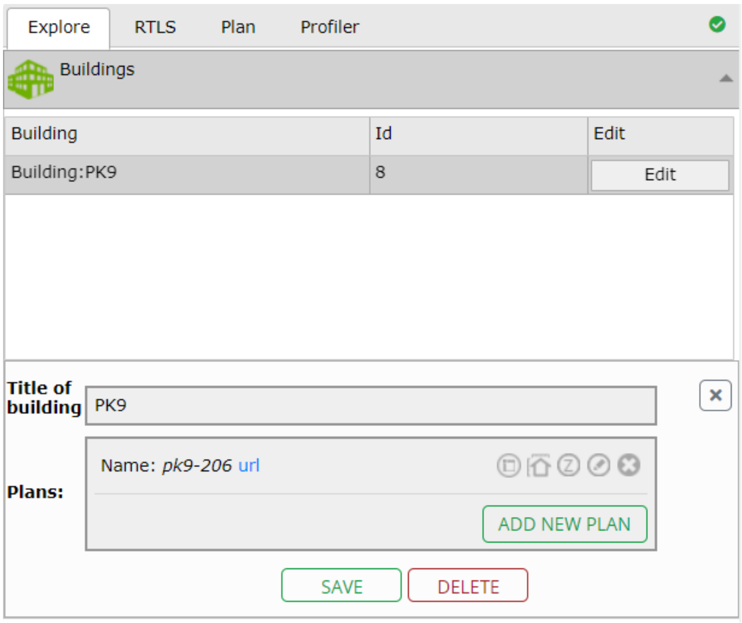

Fig.6 Adding floor plan to Sensmap

2.4 Creation of virtual zones in the floor plan

Zones are created in the Plan → Zones section, which are placed in the space based on their need. There are three types of zones that have different functions. Zones are divided into informative (info - blue color), warning (warning - yellow color) and dangerous (danger - red color) zones. If the tag enters an unwanted zone, the system receives notifications. For our purposes, we used the info zone type. We created 10 zones, since there are nine places for students and one for the teacher in the classroom.
In the next picture we see a fully set room together with zones, anchors and tags.

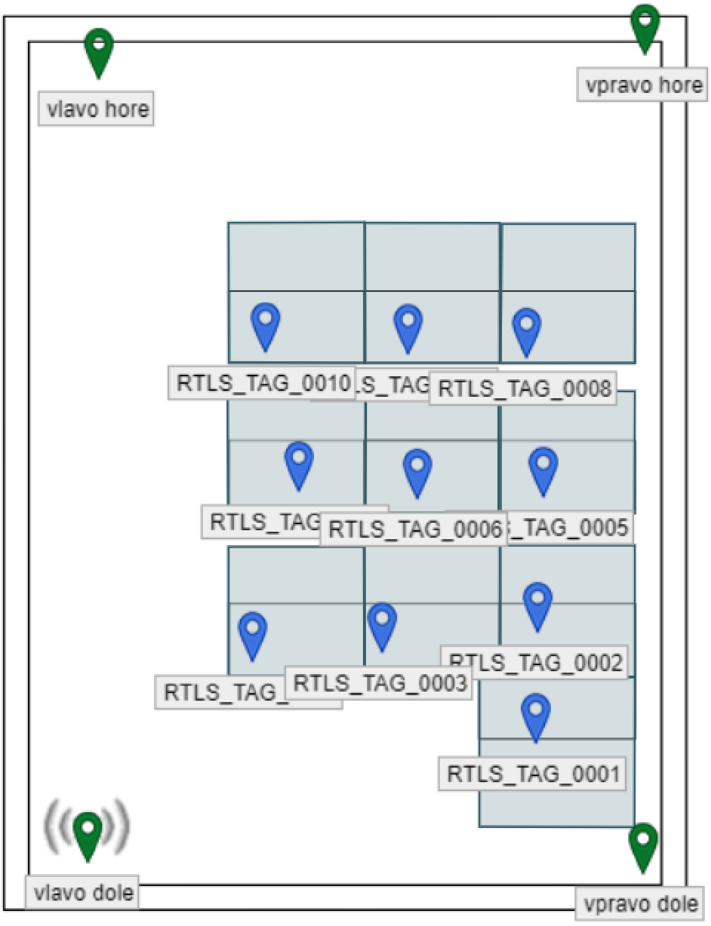

Fig.7. Fully set up laboratory 206

5. CONCLUSION

The results showed the successful creation of a mobile localization RTLS network in laboratory premises. The achieved localization accuracy was significantly high (30 cm), which confirms the effectiveness of the designed algorithm and the combination of technologies used. This RTLS network has wide possibilities of use in the field of research and development, as well as industrial applications, where precise tracking of the location of mobile devices is required.

Based on our results, it can be concluded that the creation of a mobile localization RTLS network in laboratory premises is technologically feasible and brings significant advantages. This contribution contributes to the development of localization technologies and provides a basis for further research in the field of accurate tracking of mobile devices in laboratory environments.

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APPLICATION OF PRODEUTION PROCESS INNOVATION USING SIMULATION SOFTWARE

Abstract

This article points out the possibilities of streamlining production processes based on the simulation created by the Tecnomatix Plant Simulation program. The main goal is to emphasize the importance of simulation in the change design phase. The first part describes the production process, which is divided into three parts. The main goal was to create a good model that should reflect the actual conditions on the line and to design the control logic so that the line model works like a real line. In the work, we designed the concept of a robotic workplace, moving containers with an overhead conveyor and a blasting workplace in the shipping hall. We modeled and simulated these designs to identify emerging bottlenecks, which we removed. Thanks to the simulation, we saved the company costs, since we proposed these changes as an experiment in a virtual environment without physical intervention in the line.

Key words: Production process, Tecnomatix Plant Simulation, Optimization

1. INDRODUCTION

The implementation of the necessary innovative changes in the production process is significantly affected by problems, including production interruptions [1,2]. These changes are often time-consuming, costly and the outcome is usually uncertain. It is therefore necessary to thoroughly verify the effectiveness and efficiency of these changes before they are implemented, as the simple implementation of modern technologies is no guarantee of success [3].

Today, simulation is of great importance in several areas of human life. It is the process of creating models of reality using computers [4]. Thanks to them, we can identify weaknesses and possible problems in systems and thus prevent real failures and disasters [5,6].

The article will focus on simulating the current production of air tanks. Subsequently, a second simulation will be created, in which we will apply the planned innovative technologies. The simulation model of the innovative production will be created and analyzed, and then compared with the simulation model of the current production. We will utilize graphs and statistical reports to compare these simulation models and evaluate the benefits of the proposed innovations.

2. DESCRIPTION OF THE PRODUCTION PROCESS

In the current production capacity and with the use of existing technologies, it is possible to achieve the production of air tank 10352 in the amount of approximately 50 pieces per day. All workstations require operator service. Longitudinal and circumferential welding operations are performed using automatic welding machines, which means that the movement of the welding torch is machine controlled. However, these machines do not offer spatial adaptability and the operator must constantly control the movement of the welding torch. This means that these machines cannot effectively consider the deviations caused by the curvature of the welded parts and the thermal effects that arise during the welding operation itself.

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Production takes place in two shifts, with 15 workers working on the first shift and only one worker on the second shift. Spraying of air tanks is carried out in both shifts. The presence of two painters in two shifts is essential for thorough manual cleaning of the air tanks before they are painted.

The entire production process was divided into three phases based on the information provided.

2.1 Production of the base

In the first step, the bottom is burned - a circle with a diameter of 446 mm on a Hi FOKUS plasma cutting machine made of sheet metal with the designation P275SL and dimensions of length 3500 mm, width 1250 mm, thickness 3.5 mm. Cutting one round takes 1 minute and the machine is operated by one worker. In the second step, the ring is wrapped in foil, which reduces the frictional resistance during the technological pulling operation, wrapping takes 0.5 minutes. The packed rings continue to the Zeulenroda hydraulic press where the bottom is pulled, pulling one bottom takes 0.5 minutes. The bottom is then hemmed on a Lexona rotary hemming machine, this operation takes 0.5 minutes. The operation of packing, pulling, and hemming is performed by one worker. The bottom then needs to be surface treated by pressure blasting using air. The blasting operation is carried out in another hall and a truck is used to move the parts, the blasting time of one day is 5 minutes. A hole is turned into the surface-treated bottom using an RC80 turret lathe, after turning the bottom is deepened, the whole operation takes 3.5 minutes and is operated by one worker.

2.2 Production of the shell

The input material in the form of a sheet with a length of 3500 mm, a width of 1250 mm and a thickness of 3.5 mm is divided into three smaller sheets on DURMA hydraulic shears, dividing one sheet takes 0.8 minutes. The sheets continue along the cylindrical material feeder for the next operation, where they are cut with SAND scissors to the size of the shell. The output is cut shell and waste, which represents 22 percent of the input sheet. Hydraulic shears are operated by 1 worker and the process takes 2.5 minutes. The cut casing continues to the operation of drilling a hole with a diameter of 52 mm on a MAS VR4A radial drill, with subsequent deepening of the hole, the waste during this operation represents 2.2 percent. The cut shell is surface treated by pressure blasting using air. The blasting operation is carried out in another hall and a truck is used to move the parts, the blasting time of one shell is 5.5 minutes. After the surface treatment, the cut skins proceed to the rounding operation with a 4-cylinder rounding machine Imcar 170/1575, which circles the sheet to a diameter of 350 mm. It takes 5 minutes to circle the sheet, and the operator consists of one worker. The rounded casings continue for assembly followed by longitudinal welding using a longitudinal welding machine. 0.16 kg of welding wire is used during welding. After welding, it is necessary to clean the weld. Welding takes 4.5 minutes and is operated by one worker.

2.3 Production of air tank 10352

Longitudinally welded shell assembly workplace where the shell with bottoms is assembled, the operation takes 6.5 minutes and is performed by one worker. The assembled air tank is circumferentially welded on a circumferential welding machine, the operation takes 8.5 minutes. The inside of the welded air tank is sprayed with Konkor paint and after the inside is sprayed, the threads are cleaned, and pressure tested. The service consists of one worker and the operation takes 8.5 minutes. After the pressure test, two workers screw in the hanging screw and hang the air tank in the spray booth. Another worker cleans and degreases the air tank, then sprays the air tank with a primer. The operation takes 16 minutes and is operated by one worker in two shifts. After the paint is applied, the air container passes through the drying cabin, from which it is removed by workers and transferred to the packaging workplace, where the air container is packed on a pallet and prepared for shipment. The hanging of the air container and the packaging are carried out by the same workers.

2.4 Simulation of the production process

The simulation program Tecnomatix Plant Simulation from Siemens was used to create simulations of a specific production process. In Fig.1 you can see a modeled production head in which the entire production process takes place.

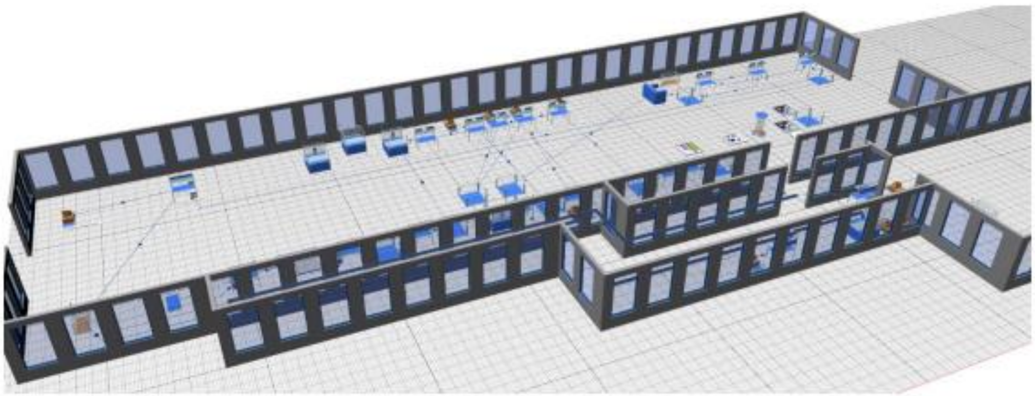

Fig.1 Production hall

The simulation time was set at 16 hours. After this 16-hour period, we provide a statistical report, which is shown in Fig.2.

Simulation time:16:00:00.0000

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
Expedícia	Paleta	43:35.5006	21	1	100.00%	0.00%	0.00%	6.88%	

Fig.2 The result of the simulation of the current production process

3. PROPOSED INNOVATION OF THE PRODUCTION PROCESS

The scientific design of the innovation of the production process includes the operations of encircling, longitudinal welding, assembly of the air reservoir, circumferential welding, pressure test and pre-cleaning of the air reservoir before spraying.

The surface-modified casing will arrive in one of the two hoppers, from where it will be moved to the conveyor belt with the help of robotic arm No. 1. The transport pass moves the casing to the robotic encircling machine, the estimated operation time is 3 minutes. The circled shell is pushed out to the longitudinal robotic welding workplace, where the longitudinal welding operation will take place, the estimated time of the operation is 4 minutes.

The prepared bottom and the bottom with the label will be inserted by the worker into the welding fixtures on the rotary table. After the parts have been inserted, the table is turned, and a shell is added to the preparation containing the bottoms from the longitudinal welding operation. After the air tank is assembled, the table is turned to the last position where the perimeter welding and the welding of the neck to the shell will take place, the estimated time of the operation is 6 minutes. Welding is ensured by two welding arms with six degrees of freedom, located in a position on the ceiling.

The welded air tank is removed by robotic arm no. 2 and moves it to the pressure test station. The arm of the testing device grasps the air reservoir and performs a pressure test with water, estimated operation time is 4 minutes.

After the pressure test, the air tank leaves on the conveyor for the operation where the interior coating is sprayed, and the hanging screw is screwed. Estimated operation time is 3 minutes. From this operation, the air tank leaves on the suspended conveyor for the blasting operation, the blasting time of one air tank is 5 minutes. From there, the air tank continues to the spray booth, where the painter no longer must perform manual cleaning of the air tank and the spraying time of one air tank is 7,5 minutes.

3.1 Simulation of the innovative production process

We have updated the simulation of current production in accordance with the proposed aspects, which are described in detail in chapter 3. Fig. 3 shows a modeled innovated workplace.

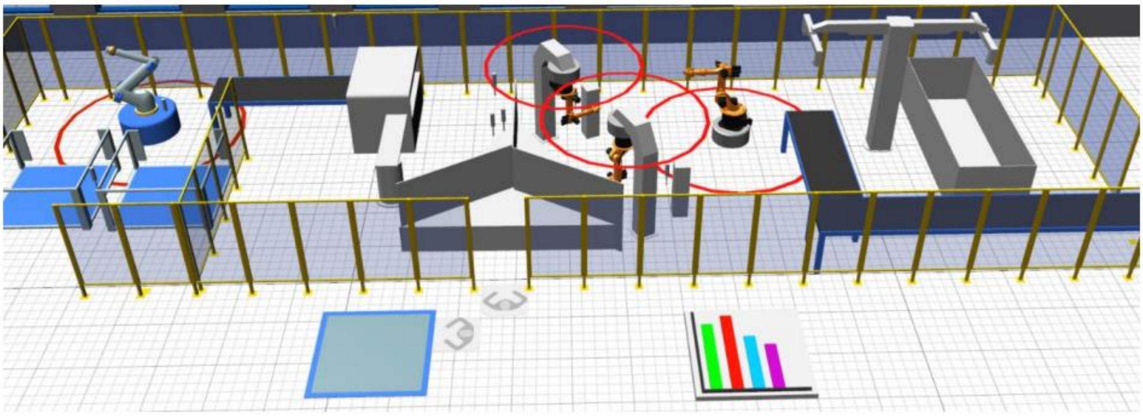

Fig.3 Innovated workplace

4. EVALUATION OF THE RESULTS

After running a 16-hour simulation, we identified bottlenecks in the bottom manufacturing process. Analyzing the graph (Fig.4), we found that the busiest workplace is workplace 14, which specializes in bottom turning. In addition, we also observed significant blocking of the "Welding Robot1" workplace.

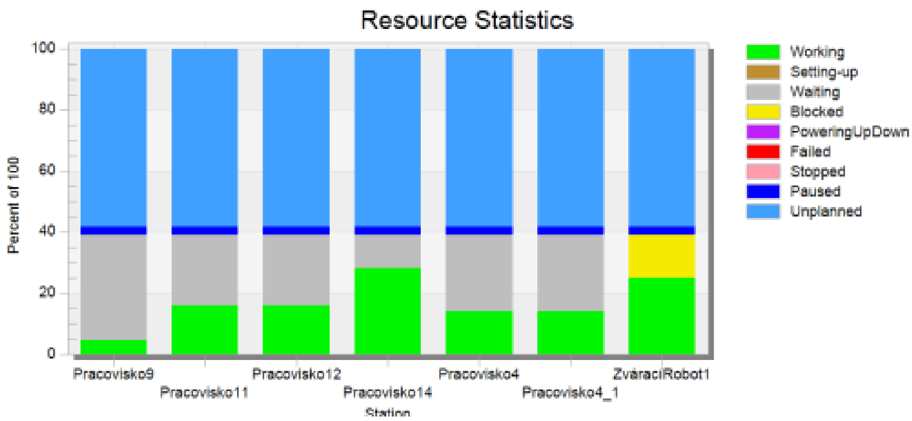

Fig.4 Utilization of the innovative production process without optimization

The resulting simulation values are shown in Fig.5. With the innovative production process without optimization, 36 pieces of the air tank were shipped.

Simulation time:16:00:00.0000

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
expedícia	Paleta	26:02.8848	36	2	100.00%	0.00%	0.00%	1.92%	

Fig.5 Resulting values of the production process simulation without optimization

For even more efficient use of the robotic workplace, the following changes were proposed, which relate to the operation of packaging, pulling, and edging, where we assigned another worker. By assigning another worker, the production of the mentioned workplaces will increase significantly. We also duplicated and created another workplace where bottom turning will be performed and changed the number of workers to two. At the same time, we assigned one more worker to the neck and bottom welding operation.

The utilization of the machines was balanced, we almost doubled the utilization of the welding workplace. Even with this step, we managed to reduce the blocking of the workplace by a factor of two, as you can see on the graph (Fig.6).

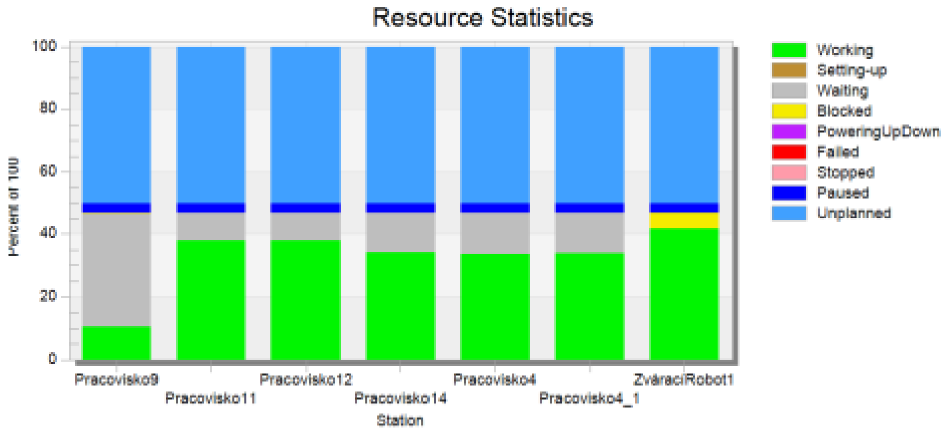

Fig.6 Resulting values of the production process simulation with optimization

With the applied optimization, we found an increase in the number of manufactured air tanks per day to 43 pieces (Fig.7) with the help of simulation.

Simulation time:16:00:00.0000

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
expedícia	Paleta	22:05.2471	43	3	100.00%	0.00%	0.00%	2.26%	

Fig.7 The result of an innovative production process with optimization

With the upgraded production process without optimization, we were able to increase production by 15 pieces compared to the current production process. Subsequently, with the innovative process with optimization, we were able to increase the production by up to 22 pieces compared to the current production.

5. CONCLUSIONS

The main goal of the article was the implementation of innovative technologies in the company's air tank production process using the Tecnomatix Plant Simulation software. In the work, we designed the concept of a robotic workplace, moving containers with an overhead conveyor and a blasting workplace in the shipping hall. We modeled and simulated these designs to identify emerging bottlenecks, which we removed.

With the modernized production process without optimization, we managed to increase production by 15 pieces compared to the current production process, where we can produce 21 pieces. Subsequently, after identifying the bottlenecks, we further optimized the process and based on this, we managed to increase the production by up to 22 pieces compared to the current production, where we can produce 21 pieces in one day.

ACKNOWLEDGEMENTS

This article was created by the implementation of the grant projects: APVV-17-0258 Digital engineering elements application in innovation and optimization of production flows, APVV-19-0418 Intelligent solutions to enhance business innovation capability in the process of transforming them into smart businesses. VEGA 1/0438/20 Interaction of digital technologies to support software and hardware communication of the advanced production system platform. KEGA 020TUKE-4/2023 Systematic development of the competence profile of students of industrial and digital engineering in the process of higher education. VEGA 1/0508/22 „Innovative and digital technologies in manufacturing and logistics processes and system “.

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Jozef TROJAN[1], Marek KLIMENT[2], Richard DUDA[3]

ANALYSIS OF PROCESSES IN TESTBED 4.0

Abstract

The article deals with the possibilities of using PLM software elements and their participation in the optimization of production processes using a virtual model, the simulation of these processes and the evaluation of the results obtained from the software that was used to create the simulation, the model. The presented article contains an analysis of all pre-production and production processes taking place in TestBed 4.0.

Key words: PLM Software, TestBed 4.0, Siemens, Tecnomatix Process Simulate

1. INTRODUCTION

In industry, opportunities for improving production processes are increasingly being addressed, which creates the need to analyze the individual parts that make up the production process, for which workplaces and laboratories with integrated elements from Industry 4.0 are used. Thanks to the analysis of these processes, the time it takes for products to reach the market is reduced and, thanks to this, the diversification of the company's offer increases. TestBed 4.0 responds to changes and market demands and brings the possibility to create intelligent industrial enterprises that are fully automated and constantly optimized thanks to the possibility of connecting production equipment with digital models. The possibilities of implementing innovative designs offered by TestBed 4.0 contribute to ensuring the competitiveness of Slovak industrial enterprises within the European market. In industrial enterprises, a large number of processes are carried out, which are necessary for the correct course of production and ensuring the delivery of the ordered product to the customer on the specified dates. Such processes take place gradually, with a certain continuity. Therefore, in order to achieve high performance of the company, it is necessary to organize and control these processes effectively in order to ensure high production efficiency in the company at the lowest possible costs.

2. PRE-MANUFACTURING PROCESSES

2.1 Communication with the customer about a potential order

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

2.2 Creating an offer for the customer

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

Fig. 1 Workplace for product data management

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

- Construction departments
    - sells his statement on the construction of the product and its complexity.
- Technology departments
    - sells his estimates for the price of material consumption, work, or cooperation.
- In stock
    - sells price estimates for materials and cooperation.

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

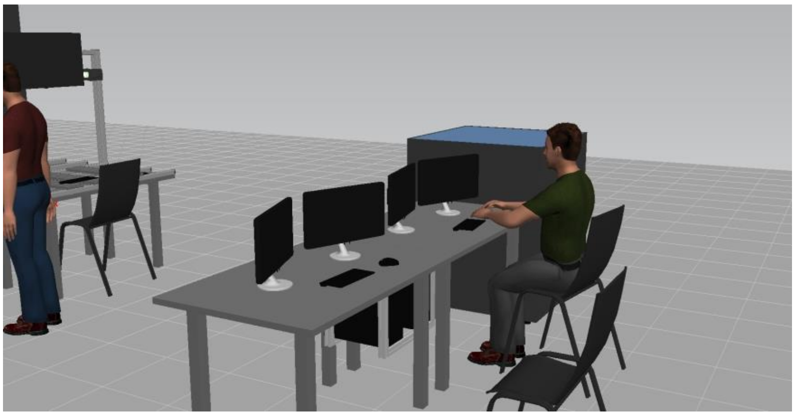

Fig. 2 Price offer processing workplace

2.3 Acceptance of the order

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

2.4 Construction department

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

2.5 Technology department

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

2.6 Stock

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

Fig. 3 Workplace for structural design verification

3. PRODUCTION PROCESSES

3.1 Production planning

This process has the task of designing an optimal production plan so that all orders are produced at the agreed time, while ensuring that production is not too complex and everything is produced as quickly as possible, with the highest utilization of people and machines in the company.

Fig. 4 Workplace optimization of production procedures

The production planning section is responsible for creating the plan, which takes care of the effective implementation of technological processes into the current production plan and takes into account across the entire company:

- Material stock.
- Cooperation with other companies.
- Priority orders.
- Order delivery date.
- Production capacities.

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

3.2 Production management

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

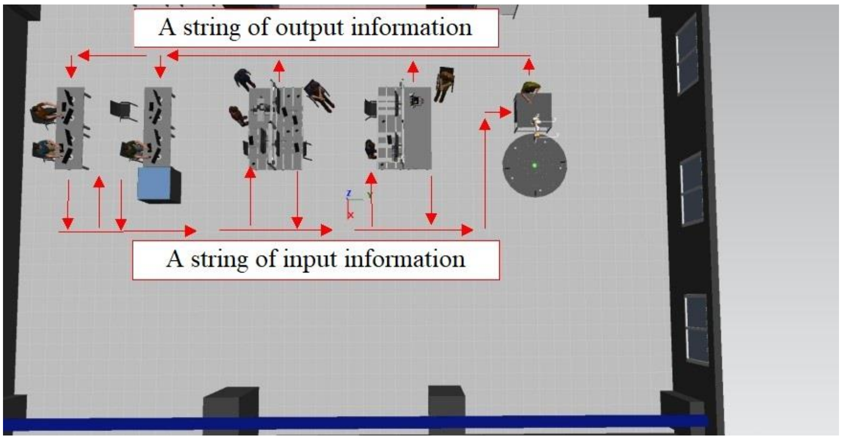

Fig. 5 Information flows within workstations

3.3 Shipment of the finished product

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

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

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

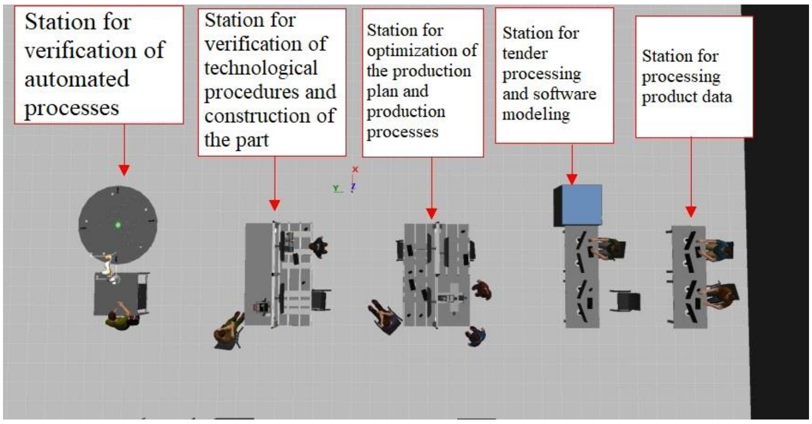

Fig. 6 Layout of the workplace

4. EVALUATION OF THE ANALYSIS

Analyzing individual pre-production and production processes allows us to identify and determine the probability of errors, bottlenecks in these processes and propose a solution using PLM software elements, which leads to the acceleration of these processes and the efficiency of the entire enterprise.

Tab. 1 Streamlining processes thanks to PLM software

Pre-production and production processes	Before PLM software	After implementing PLM softwares	Average efficiency in %
Creation of drawing documentation	Incomplete technical documentation. Inadequate design solutions.	Automated creation of drawing documentation. Verification of the correctness of the structural solution in the simulation. Access to centralized libraries.	5-10 %
Creation of technological documentation	The need for physical verification of procedures - increases costs.	The possibility of verifying procedures in the digital environment and making them more efficient.	5-15 %
Planning of production	Low efficiency of production plans. Inefficient material flows.	Streamlining production plans thanks to the possibility of their verification in digital models and more efficient design of material flows in these models.	10-20 %
Production management	Slow reactions to changes in production. Low overview of the situation in production.	Machine load monitoring thanks to PLC units increases the overview of the state in production. The possibility of tracking the movement of the material flow in production using the RTLS system.	10-20 %

Shipment of goods	Lack of transparency about materials in warehouses. Shipment of incorrect products.	Creation of a central database of material and products thanks to the use of a database with barcodes and readers of these codes. Localization of materials in the warehouse using the RTLS system.	5-10 %

5. CONCLUSION

The use of PLM software elements in the TestBed 4.0 environment allows us to create an accurate model of the production process, by analyzing which we are able to detect shortcomings and bottlenecks in this process and propose adequate solutions, which we will then use to adjust the simulation of the production process. The high costs of expanding production capacities due to the need for physical verification of the production process may deter some companies, but thanks to PLM software that allows us to verify new concepts at the level of digital production simulation, these concerns are decreasing and industrial companies are increasingly expanding their portfolios of offered products thanks to the possibility of quick prototyping of new products, using various software solutions from the field of PLM and CAD modeling.

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Branislav MIČIETA[1], Vladimíra BIŇASOVÁ[2], Beáta FURMANNOVÁ[3]

THE USE OF MODEL OF AN AUTOMATED WAREHOUSE

Abstract

The paper deals with the multifunctional kit is a robust training model that simulates and demonstrates warehouse automation in the world's most advanced enterprises. Programming takes place in the Siemens TIA Portal software, which is then loaded into a Programmable Logic Automator which is interconnected with the source Siemens SITOP PSU100S. The main objective of the paper was to provide an overview of the current state-of-the-art in automated manufacturing and to create an example of an automated warehouse that can be used in teaching as an ideal simulation and demonstration model for training and industrial automation.

Key words: Automated warehouse, software, PLC

1. INTRODUCTION

The main objective of this paper was to provide an overview of the current state of the art in automated manufacturing and to create an example of an automated warehouse that can be used in Department of Industrial Engineering training, simulation, and demonstration model for training and industrial automation. The automated warehouse model example offers the opportunity to continue developing and extending the model and creating an experimental manufacturing system in a selected laboratory at the Department of Industrial Engineering, Faculty of Mechanical Engineering, at University of Zilina.

The vision of Industry 4.0 [1-2] is to achieve a highly automated and autonomous manufacturing environment in which decision-making processes are provided by a variety of technologies that rely on the collection and subsequent analysis of input data performed in real time. Newly explored technologies can often transform entire industries. The expansion of the engineering industry increasingly requires the use of state-of-the-art technologies in the field of production to achieve significant labour productivity and optimisation of the production in question. At the same time, with the increase in higher demands on the products or services produced, there is a need to speed up the production process as much as possible, but at a cost, that maximises the quality of the product. This is why automation is also being used. [3]

The efficiency of production is constantly conditioned by the work of pre-production components (construction, technology, design). [4] The role of the engineer is to analyse the already used, but also newly created working procedures [5-6], to discover the best method to perform the work (optimal working method). The best working method is generally considered to be is the one in which the cost of performance is minimised as much as possible. [7-8] An effort is to make each work operation as short and simple as possible, so that it can be more easily learnt and at the same time require a minimum of human effort to perform.

2. METHODS

As an example, a Programmable Automated Warehouse Model was created (Fig. 1). This multifunctional kit from Fischertechnik [9] is a complete, stable training model that is used to simulate and demonstrate warehouse automation in the world's most advanced companies. A transfer/transport

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station with conveyor belt, a shelf stacker (3-axis robot) for stacking and retrieving special workpiece carriers, storage rack with nine storage slots.

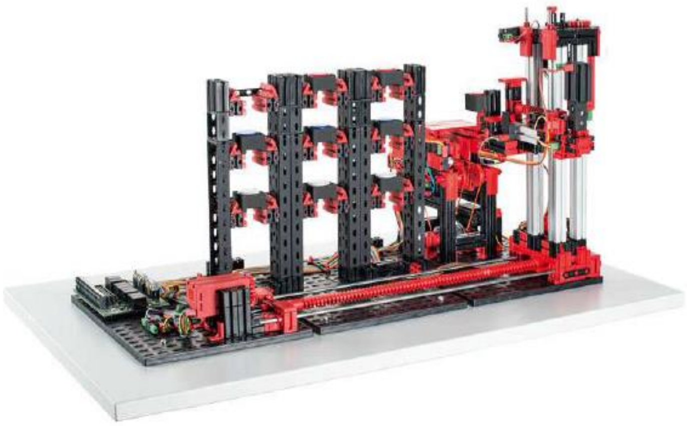

Fig. 1 Transport station with conveyor belt

The procedure for running the automated model:

- Acquisition of the kit and subsequent repair of components that have been damaged repairing the components damaged during transport.
- Installing the Siemens TIA Portal software to verify the functionality individual components.
- Connecting the power supply to the network.
- Connect the commissioned power supply to the PLC.
- Interconnect the PLC to the kit, via the circuit board with the change relay direction of rotation of the motors.
- Checking the wiring and subsequent rewiring to make the individual components work correctly.
- Familiarization with the programming language, the individual parts of the block programming.
- Programming a particular part of the model, using individual inputs and outputs.
- Loading a given program into a Programmable Logic Automata. Subsequently running the program and monitoring the individual components in motion.
- Redesign/Improvement of programmed block.
- Printed circuit board with relay.
- Connecting the PLC to the kit and the power supply.

In order to be able to work with the automated warehouse model further it is it is necessary to connect it with a PLC Programmable logic controller (Programmable logic automaton) + Siemens SITOP PSU100S 24 V/5 A power supply for mounting rail (DIN rail) 24 V/DC 5 A 120 W. A programmable logic controller or PLC can be described as a relatively small industrial computer used to control a variety of industrial processes. The control takes place in real time. A PLC is also typical in that the program that controls it is loaded in cycles, unlike everyday computers, PLCs are designed to be directly integrated into the manufacturing process and because of this have customized peripherals. Such computers have a standardized construction, according to the IEC-1131-(x) standard. In terms of design, PLCs can be divided into the following groups:

- compact,
- modular.

The compact PLC has a fixed and immutable structure that cannot be modified or extended. Everything that the PLC needs to function, such as the CPU and other input/output peripherals, is combined in one unit. A modular PLC is a PLC that can be modified or expanded. Such a design allows almost unlimited modification of the input-output peripherals. [6] The program processed by the PLC is mostly subject to the IEC 1131-3 standard, which defines programming languages such as:

- Instruction List IL,
- Structured Text ST,
- Contact Diagram Language (Ladder Diagram LD),
- Function Block Diagram (FBD). [10-11]

Connection to PLC control: The model has a relay to change the direction of rotation of the motors. All inputs and outputs can be connected to a jack connector (26-pin, 2.54 mm pitch) or to serial terminals with socket clamps. The Simatic S7-1200 Basic Controller PLC product is shown in Fig. 2. This product is described as The Simatic S7-1200 Siemens PLC Basic Controller is a high-performance system with a compact and space-saving design. This CPU PLC has 2 integrated analog inputs, 6 integrated digital inputs and 4 integrated digital transistor outputs. It comes with integrated IO and communication interfaces to meet the highest industrial requirements. This is also made possible by a range of powerful integrated technology features that make this controller an integral part of a complete automation solution. The controller is at the heart of a new offering for simple but high-precision automation tasks.

It is the ideal choice when it comes to performing automation tasks for a range of applications in the low to medium power range with maximum flexibility and efficiency. [12]

Thanks to standardized remote control protocols, you can connect the controller directly to your control to your control centre without any programming. The Siemens SITOP PSU100S 24 V/5 A DIN rail mount power supply 24 V/DC 5 A 120 W.

Fig. 2 PLC Simatic S7-1200

The SITOP smart power supply is one-third smaller but has more power is one of the narrowest DIN rail power supplies and has excellent overload behavior. Even high loads can be switched on without problems. Rated outputs of 120% consistently make the power supplies the most reliable of their kind. Numerous certifications facilitate universal and worldwide use as well as use in potentially explosive areas. Overview of benefits:

- Rounded power range from 60 to 960 W for universal use.
- Compact design from 32.5 to 150 mm wide for small mounting area.
- Easy DIN rail mounting. Extra power: 150% of rated power for 5 seconds as reliable protection against
- Overload protection - for trouble-free switching of DC/DC converters, motors and loads with high surge currents. More power through sustained 120% of rated output up to 45°C.
- Large output voltage adjustment range up to 28 V, easily accessible from the front by potentiometer.
- Parallel connection to increase power output is possible. Input voltage 120 V (85 - 132 V) / 230 V (170 - 264 V).

3. RESULTS

SIEMENS TIA Portal (Totally Integrated Automation) gives the possibility to write a program for control elements such as PLCs but also HMI panels, essentially integrating all design processes for automation in 1 software. Historically this has been divided into 2 non-core software but today TIA Portal allows programming of PLCs, HMI panels but also different peripherals. This makes the work easier but mostly saves time and money in the programming stations or different industrial machines.

Programming takes place in the Siemens TIA Portal program, as the 1200 series module is used in the work, moreover, the TIA Portal is used not only for programming PLCs, HMI panels but also various other peripherals provided by Siemens. Therefore, it can be defined in 2 big groups namely PLC programming and programming resp. Animation of the HMI interface for the user. The TIA Portal program has these two groups integrated in one program and hence it makes the job of the programmer easier. Since some projects may involve many inputs, outputs or different variables that may not only be input / output but also in a version processed internally by the PLC processor.

PLC programming is carried out in the following way and that is that the programmer has to clarify the subsequent sequence of steps that lead to the solution of the problem and when the next step should occur. Subsequently, the task, i.e., if it is complex and large, has to be divided into smaller subgroups and chronologically these subgroups have to be set up in such a way that they are correct. We can make such a division by assigning all the action members to one group but in principle, the division is a matter of the programmer and his habits.

The program is uploaded to the PLC via the TIAPORTAL program (TIA Portal V17) as follows. It is necessary to select the PLC in my case (PLC_1 [CPU 1214C DC/DC/Rly]), right click and select the option (Download to device) and then (Hardware and software). The next step is to check if the program has been loaded correctly, you need to mark Go online in the top bar and check if there are green balls everywhere in the (Project tree). This indicates whether the program in the PLC matches the program that is currently loaded in TIAPORTAL. If the color orange is present, this indicates that the block at which the orange ball is located is different. If the ball happens to be red, an error has occurred, but this condition usually only occurs on the physical PLC.

4. CONCLUSION

The work focused on new trends in the field of automated production. Automation nowadays is an essential part of a mature enterprise on an international level. The introduction includes a study dealing with the current state of automation in the world, and then the advantages and disadvantages of automation are mentioned, with the advantages outweighing the disadvantages.

The third chapter provides a graphical representation of the importance of mechanization and automation, followed by an example of automation technology on a programmable model of an automated warehouse, along with the various points of how I went about running the model. The programming is done in the Siemens TIA Portal software, which is then uploaded to the Programmable Logic Automat or, which is interconnected with the Siemens SITOP PSU100S power supply. The main objective of the paper was to provide an overview of the current state of the art in automated manufacturing and to create an example of an automated warehouse that can be used in teaching in the Department of Industrial Engineering as a training, simulation, and demonstration model for training and industrial automation. The automated warehouse model example offers the opportunity to continue to develop and extend the model and create an experimental manufacturing system in a selected laboratory.

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MODELING OF 3D OBJECTS AND METHODS OF THEIR APPLICATION AND PRESENTATION WITHIN THE SIMULATION AND BEYOND

Abstract

In the 21st century, most of the world's leading companies use simulation programs to simulate various processes. These programs make it possible to record the entire process in the smallest details and thus eliminate bottlenecks, deficiencies and various errors that could occur during real production. The simulation will ensure that we track the entire production process even before the start of real production, so that it is clear that production will be as efficient as possible without any downtime and errors. These simulations can be variously detailed and detailed. It can be details from the point of view of the process, or from the point of view of the elaboration of details from the visual side. In the case of process details, it is necessary to analyze and evaluate all accessible data as part of the processing of the simulation, or supplement it with other necessary data, so that the accuracy of the simulation is as similar as possible to the real object. In the post, we will focus more on the other side of the detailed simulation. For 3D objects that need to be modeled and then they can be used and interpreted in different ways.

Key words: Production process, Tecnomatix Plant Simulation, 3D Visualization, Model, Modeling,

1. INDRODUCTION

The contribution is oriented to the means of 3D visualization and the application of models within the simulation software Tecnomatix Plant Simulation, as well as the application and presentation of models in various forms outside the simulation. The software itself offers the possibility of using models that are accessible in its own library. These are basic models of some machines, conveyor belts, various types of transport vehicles and the like. From this menu it is possible to change the graphics of all objects in the simulation.

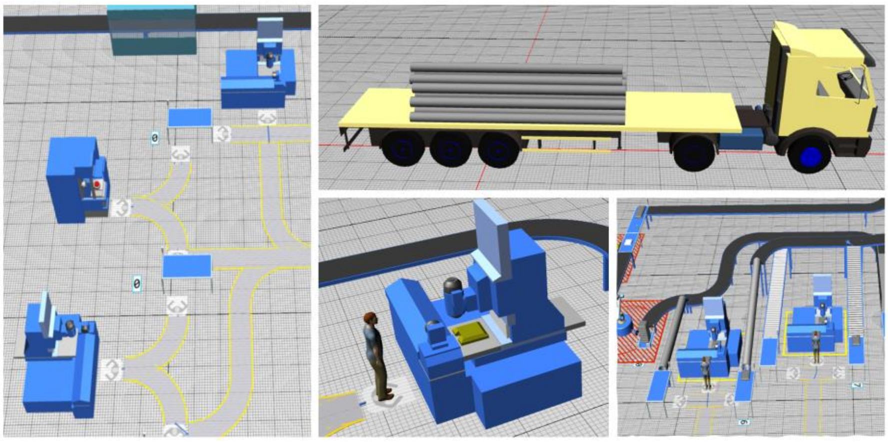

Fig. 1 3D objects from the TX Plant Simulation library

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2. CREATION OF 3D MODELS

In addition to changing the graphical display of the simulation objects to the default graphics offered by the software, the software also offers a link to CAD software. This connection is not unusual, since in most simulations it is necessary to have exact dimensions and other specifications of individual devices or components. This ultimately means their complete processing using CAD software. Of course, the connection between simulation and CSD software is not direct and integrated. For this simulation, we used SolidWorks CAD software from Dassault Systemes SolidWorks Corporation. Since the production process was focused on the production of a bearing puller (Figure 2), the individual parts were distorted and subsequently exported in the appropriate file type so that they were readable by the simulation software and thus connected within the simulation. Before the actual distortion of the parts within the software, this operation is preceded by drawing documentation. Drawing documentation in digital form is also one of the output options of SolidWorks CAD software.

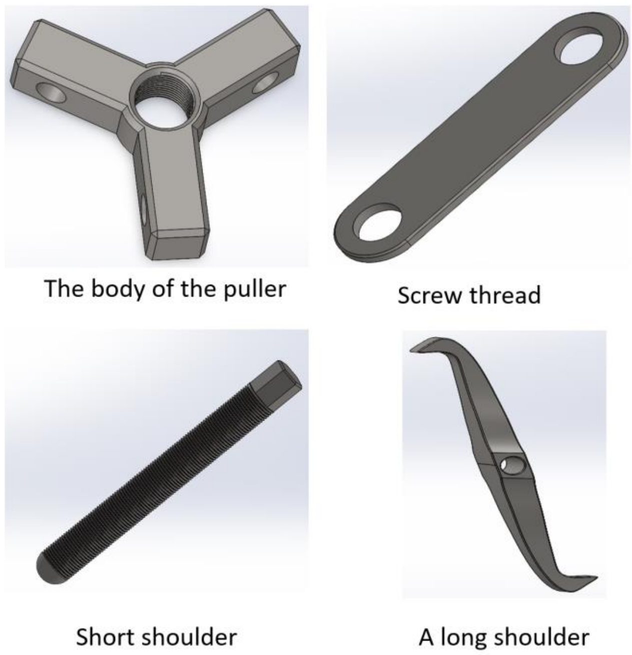


Fig. 2 Puller body parts

The puller body serves as the skeleton of the entire part, therefore this part, as well as its process, is the first part of the production, which was described and optimized in the previous chapter. As already said, since it is the skeleton of the entire final product, this part enters the assembly process first. As the second part, a screw is screwed to it in the central hole with an internal thread, which provides us with pressure on the bearing that needs to be dismantled. This screw is designed in such a way that it does not degrade the surface when it touches the surface of the part being moved. It is finished with a hexagonal head for the use of a ring or open-end wrench. Several pieces of the short arm are attached to the body of the puller at the assembly site by the production equipment, in the number of six pieces. This short arm ensures the movement and thus the overall adaptation of the long arms to the size of the part being moved. The long arm is the last part, so its assembly is also the last process before the actual packaging and shipping. Due to its shape complexity, this part was designed using casting technology. This component, as mentioned above, comes into the simulation as a purchased item that is delivered directly to the assembly site. The overall finished product, consisting of the parts shown above, can also be assembled with the help of CAD software, thus simulating all its functional parts and possibly removing any errors that might occur. This assembly is also composed of standardized parts, such as nuts, bolts or washers. All these standardized parts are subject to ISO standards, which we follow and strictly adhere to when designing these parts. In CAD software SolidWorks, all these non-standardized parts are available in the library. For the purpose of complete project documentation, this software also has the option of drawing documentation of the overall assembly. One of the specifics is also the definition of the exact type of material and thus the calculation of the total weight of the manufactured part.

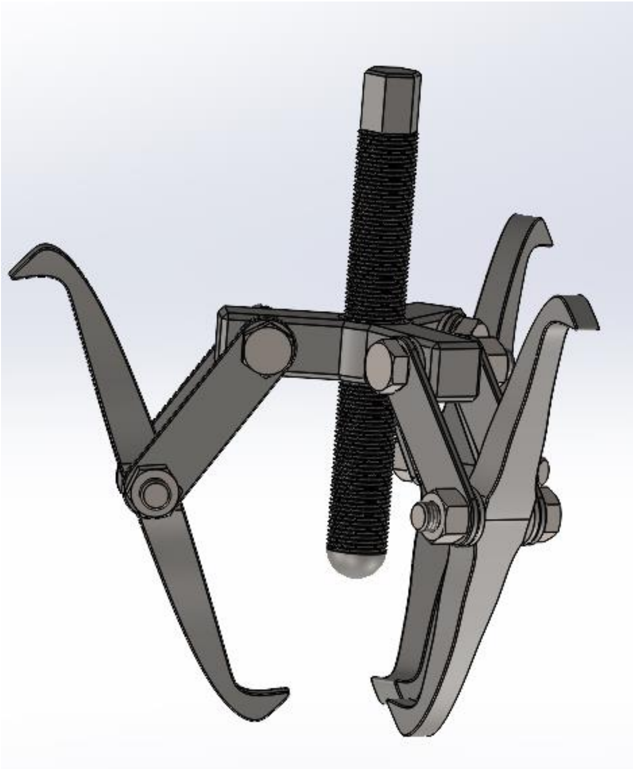


Fig. 3 Overall lineup – The puller

2.1 Import of 3D objects into the Plant Simulation environment

All 3D models distorted using CAD software can be inserted into the simulation as part of the material flow. Again, this is a similar method as it was with inserting objects from the already default library of the simulation software. Within the CAD software, the given model is exported in the form of a file with the extension STEP. This shape of this file guarantees easy conversion of the given file to another file type. With the help of a freely accessible Internet converter, the given file is converted to the JT file type, which is necessary for the simulation.

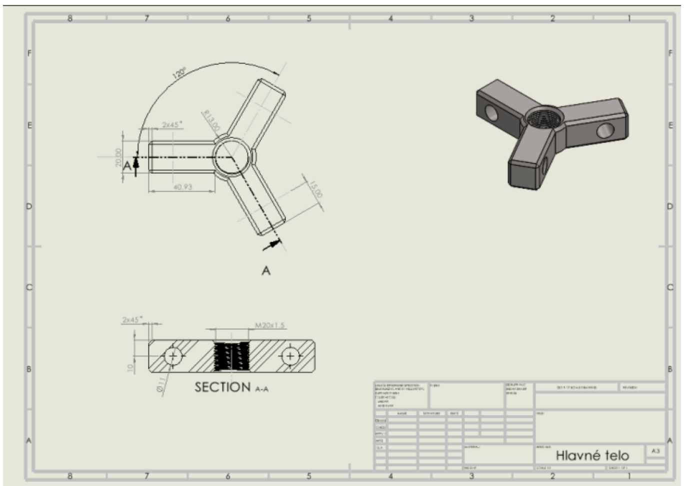
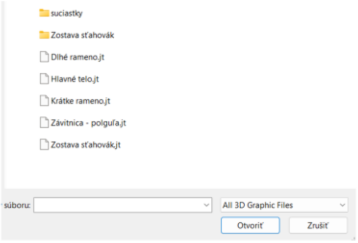
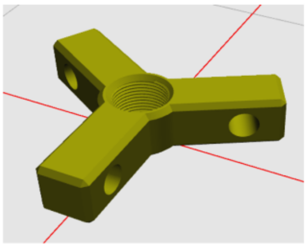


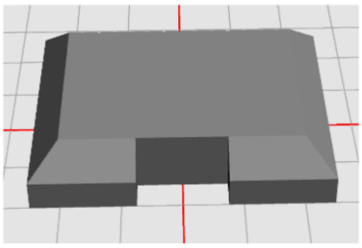
Fig. 4 Drawing documentation created using CAD software



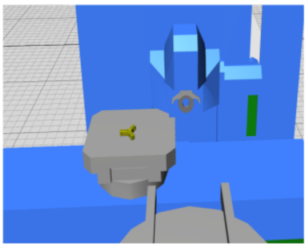
Selection of the converted JT file



Custom graphic display of the puller's body in simulations



Default graphic display of the puller's body in simulations



The puller body clamped at the milling workplace

Fig. 5 Importing models into the simulation

2.2 Possibilities of output and presentation of the simulated production process

Virtual reality, also known as VR, can be used for representative purposes of the simulated production process. This technology is known and also often used in training operators of individual assembly equipment. This simulation is also ultimately connected to VR.

VR Headset Oculus Rift S

Aplication Oculus

Aplication Steam

Fig. 6 Resources for VR

The Steam app handles communication between the simulated manufacturing process and the Oculus app.

2.3 3D print

One of the other technologies that can be used in the visualization of the production process or manufactured part is 3D printing. In order to better confirm the exact dimensions of the part, one of the forms of additive manufacturing is also used in practice. It is also used to represent the result of the entire production process. 3D printing technology is also used in solving this work.

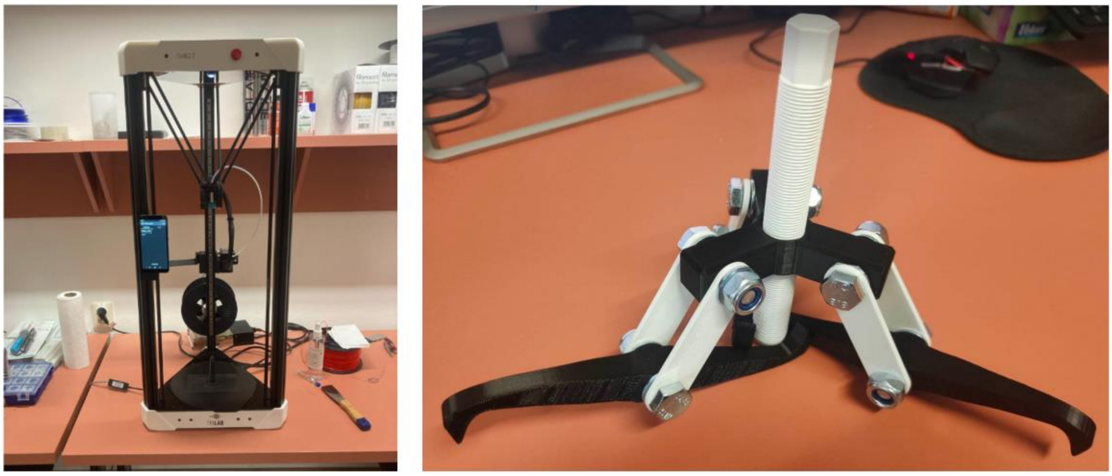


Fig. 7 3D printing of a bearing puller

2.4 Holographic image

In addition to their use in simulation, 3D printing and virtual reality, a so-called holographic projector can also be used to visualize and present the created models. A normal image captured by a camera or video camera is two-dimensional. This means that it does not display the space, but its interpretation on the desktop. Although we have some techniques to overcome the "flatness of a two-dimensional image" - we know them, for example, from 3D cinema - but they are not truly spatial, because even if they can create the impression that some parts of the image are closer than others, they lack the so-called parallax. This is what we call the difference in the position of two different points on the same image when viewed from different angles. If you move 5 seats to the right in a 3D cinema, you will still see the same image. If it were a hologram, you would see the whole scene from a slightly different perspective, and therefore you could partially look behind some of the displayed objects. There are many "semi-holograms" and optical illusions of three-dimensionality, but there are only a few real holographic methods, they can be created only under very specific conditions with the help of specialized tools. If we simplify everything, the basic method of capturing a hologram works like this: we aim a laser at a semi-transparent mirror, which splits its light into two beams. One continues on to the object from which it is reflected, the other is reflected only from the next mirror. The two rays eventually meet on the photographic film, where their interference pattern (interference = mutual influence) is created, and that is exactly what a hologram is. However, it is only recorded this way. If we want to display the hologram, we have to illuminate the recording on the film in a similar way to the way we created it.

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This is what a real hologram looks like. It is one holographic image taken from two different directions. You may notice that you see something different in each photo - as if you were looking at a real scene. There are many "semi-holograms" and optical illusions of three-dimensionality, but there are only a few real holographic methods, they can be created only under very specific conditions with the help of specialized tools. If we simplify everything, the basic method of capturing a hologram works like this: we aim a laser at a semi-transparent mirror, which splits its light into two beams. One continues on to the object from which it is reflected, the other is reflected only from the next mirror. The two rays eventually meet on the photographic film, where their interference pattern (interference = mutual influence) is created, and that is exactly what a hologram is. However, it is only recorded this way. If we want to display the hologram, we have to illuminate the recording on the film in a similar way to the way we created it.

However, this technology is not yet adapted to recording and reproducing moving objects, since no one has managed to create a moving image that would be believably sharp and smooth. Also for this reason, when trying to create a spatial image, we rely on technologies that have certain limits and do not create real holograms. However, they can create effective illusions, and this is often enough.

Rotating holographic projector

Probably the most common attempt to create a holographic effect is a rotary projector. Such a "holographic projector" consists of rotating arms on which RGB diodes are placed. When the arms spin like a fan, the LEDs start flashing. The arms rotate so fast that our eyes cannot perceive them, and the blinking of the LEDs is precisely synchronized with the speed of rotation, so that the colors are always displayed in a certain place of the circular "display area". The colored light image thus appears to be transparent and creates the impression that it is floating in space. Of course, the whole picture lacks any spatiality. The arms of the "holographic fan" only create a surface with their movement, and the result is a two-dimensional image. This means that these fans do not create holograms, but transparent 2D images.

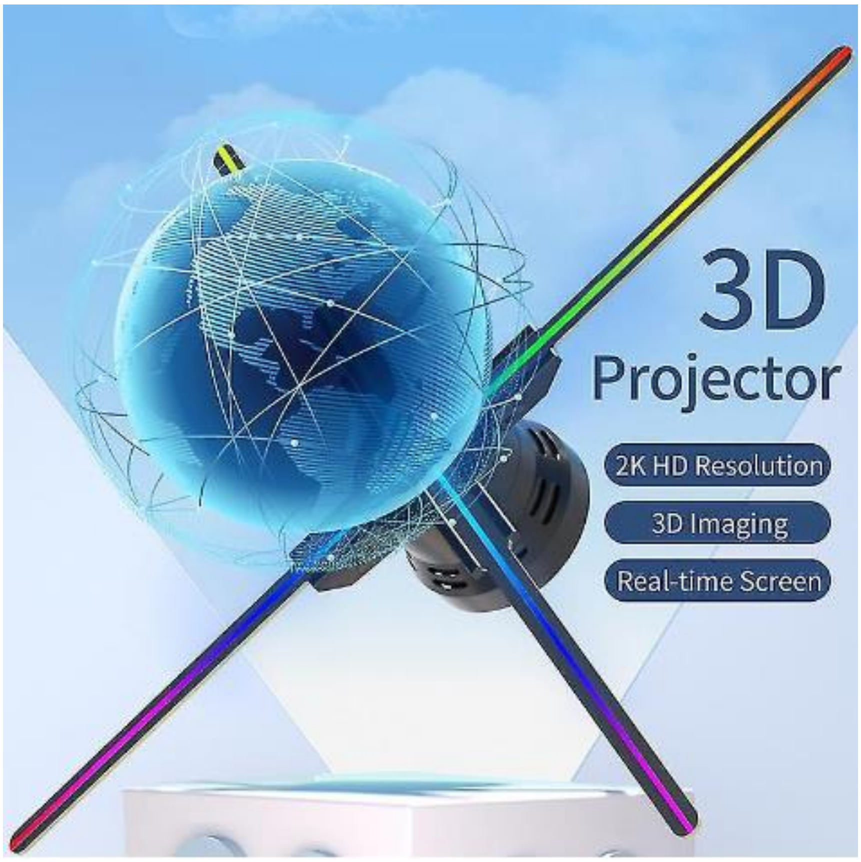

Fig. 8 Rotating holographic projector

3. CONCLUSIONS

The simulation part of the work is the result of investigating the issue of visualization in making the production process more efficient. The capabilities of the simulation software and the combination of various simulation inputs and outputs benefit the design and better understanding of the proposed manufacturing process changes. By inserting your own 3D objects into the simulation of the production process, the simulation reflects a real production line, which ensures maximum benefit, since the Tecnomatix Plant Simulation program has a limited library of machines and their parts. By replacing the models with your own models, a kind of sketch for the digital twin is created.

The conclusion of the practical part is oriented to the description of the connection of own 3D objects, drawn using the modeling program Solidworks, together with the simulation. The content of this section is also the creation of own objects as well as the project documentation of objects, subsequent editing into the required type of file needed for connection with the simulation. Subsequently, the models can be used to print physical objects using 3D printing technology, or by displaying them on various types of holographic projectors.

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