TRANSPORT & *LOGISTICS:*
the International Journal

Article history:
Received 11th December 2023
Accepted 18th December 2023
Available online 20th December 2023

ISSN 2406-1069

Article citation info: Pekarčíková, M., Trebuňa, P., Klimen, M., Matiscsák, M., Dic, M., Streamlining processes and their digitization with the help of simulation and visualization. Transport & Logistics: the International Journal, 2023; Volume 23, Issue 55, December 2023, ISSN 2406-1069

STREAMLINING PROCESSES AND THEIR DIGITIZATION WITH THE HELP OF SIMULATION AND VISUALIZATION

Miriam Pekarčíková[1], Peter Trebuňa[1], Marek Klimen[1], Matúš Matiscsák[1] Michal Dic[1]

[1] *Technical university of Košice, Faculty of mechanical engineering, Department of industrial and digital engineering, Park Komenského 9, Košice, Slovakia*
miriam.pekarcikova@tuke.sk, peter.trebuna@tuke.sk, marek.kliment@tuke.sk, matus.mastiscsak@tuke.sk, michal.dic@student.tuke.sk

Abstract:
In the 21st century, most of the world's leading companies use simulation programs to simulate various processes. Software aimed at modelling and simulation greatly increases productivity and efficiency in the creative activity of workers and opens the potential for interactivity of workers in the value chain of the enterprise and in real time. The result is shorter development time, higher product quality, data collection, management and processing, and less expensive physical prototypes. 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 the tracking of the entire production process even before the start of real production, so that the production will be as efficient as possible without any downtime and errors. The aim of the article is to highlight the issue of simulation and the introduction of Industry 4.0 principles into companies to increase the overall efficiency of business processes.

Key words:
Modelling, simulation, process, digitalization.

INTRODUCTION

In the Industry 4.0 environment, there are connected computers and intelligent machines that communicate with each other, interact with the environment, and finally make their own decisions with minimal human intervention in this decision-making process. The digitization of production and business processes and the introduction of smarter machines and equipment can offer several benefits such as production productivity, production efficiency, resource efficiency, and waste reduction. In contrast, the increased speed of production brings with it certain disadvantages.

The increased speed of production due to industrial automation will also increase the consumption of resources and energy and thus increase pollution. From the point of view of social development, it is expected that the digital transformation and restructuring of the industry will strongly disrupt the labour market. Experts believe that digitization and the advent of technologies that save physical work will eliminate most jobs with lower qualifications and at the same time create fewer job opportunities in various fields.[2] [3, 4].

1 THE FIRST INNOVATION CENTER IN SLOVAKIA

The TestBed 4.0 (see Fig. 1) laboratory premises are located on the premises of the Technical University in Košice, specifically on the premises of the Department of Industrial and Digital Engineering. TestBed 4.0 was created to meet the demand for companies brought about by the fourth industrial revolution, also known as Industry 4.0, and as a support system that serves companies as a tool to increase. your competition's ability. In a general sense, TestBed 4.0 has a great benefit for companies that want to design, test, and search for the optimal solution for their production processes. All this means that companies go through digitization and start working more efficiently.

TestBed 4.0 works with a large amount of data, from the design of the product through its logistics operations, to the actual production of the given product. This specialized workplace offers both a high-quality background and the collection of this information from production, and finally, the advice of experts who evaluate this data and further communicate with companies about these blind spots in production and propose optimizations to make them more efficient. A big advantage of TestBed 4.0 is that it can create a solution for each business tailored to its requirements.

Fig.1 *TestBed 4.0 - a workplace oriented towards solving the practical needs of Industry 4.0*
Source: Own processing

The possible solutions include the procedures, concept and methodology of Industry 4.0 pre-applications, which means complex data collection, data collection, exchange and transformation of this data into necessary information. A very essential part of the design, verification and optimization is the correct application of the digital twin. Its presence helps control the ecosystem of an industrial enterprise, which includes:

- CAM systems,
- PLM,
- CAD systems,
- RTLS,

- production machines,
- monitoring of energy costs during production.

TestBed 4.0 provides services to industry companies that allow them to design, test and optimize solutions created according to their requirements based on Industry 4.0 applications, which can also be explained as the fact that each area can be connected and subsequently applied to each other. The TestBed 4.0 workplace allows you to plan and verify the entire production process in detail from the birth of the product, within the overall value stream of the product, and also to create very precise variants of solutions from which the company chooses the verified and most suitable variant. This means that the client is not forced to stop or interrupt production because he wants to make a change, and if this change is not effective, he can lose a lot of time and resources for further changes. Each change can be tested on digital model, into which the real situation and the current state of the process are projected. Subsequently, these changes are transferred to the real process.

The benefit of this workplace is that companies avoid many risks and can quickly and efficiently change, test and subsequently implement innovations in their operations. The TestBed 4.0 interface is unlimited from the point of view of the application of common and specific needs of digitalization of an industrial enterprise. This technology can help especially small and medium-sized enterprises to establish themselves in the market. These firms cannot afford to make a mistake in terms of strategic decisions, given the competition of other firms, because it could cost them their existence, especially in the current economic uncertainty caused by the pandemic.

2 PROCESSING OF THE SIMULATION MODEL IN THE TX PLANT SIMULATION ENVIRONMENT

The production process was designed and streamlined in laboratory conditions. This process is focused on the production of individual components and the subsequent assembly of the bearing puller. Individual components are produced at separate workplaces and are moved to the assembly workplace using various transport options. The total production consists of two separate buildings. The first building is the production hall for the production of the puller body (see Fig. 2).

A suggestion to improve this problem is as follows. The input of the semi-finished product to the production line is set in an interval (see Fig. 3), which simulates the time required to perform the next operation and thus reduces the wear of the conveyor belt due to the large load on its total length. This interval is triggered cyclically after each unloading of material on the conveyor belt.

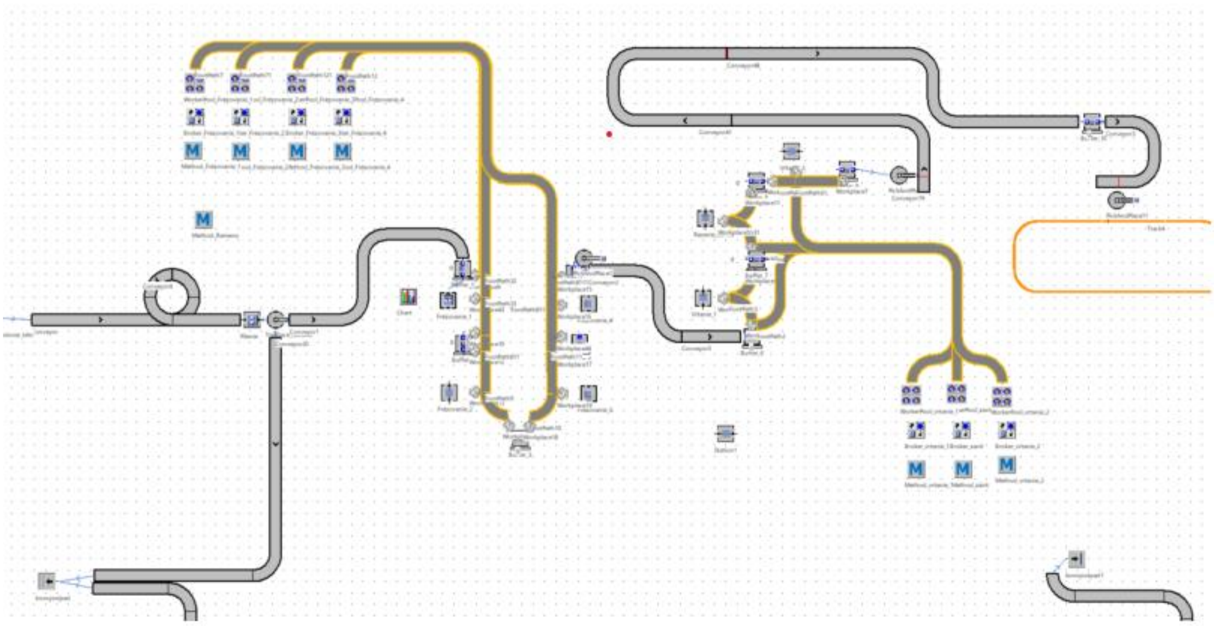


Fig.2 *Production hall of the puller body*
Source: Own processing

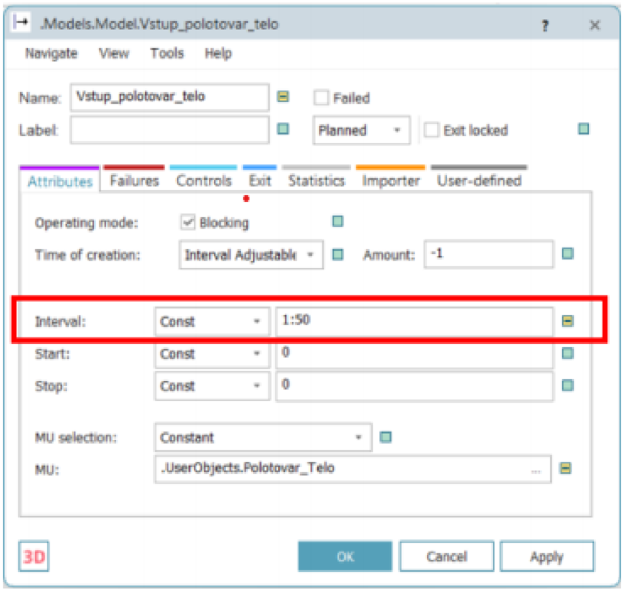


Fig.3 *Input of the blank with the selected interval*
Source: Own processing

The semi-finished product travels on a conveyor belt to the next production process, which is the division of the material. This workplace (see Fig. 4a) divides the material using a bandsaw. This process is limited due to the manual removal of metal filings and thus longer downtime during their cleaning. The optimization of this workplace is the automatic transfer of material and the possibility of automatic removal of sawdust, secured by a robotic arm (see Fig. 4b), thus reducing the downtime associated with this issue. The sawdust then goes on a conveyor belt to the iron waste warehouse. With the help of a robotic arm, the transfer of the separated material to the next conveyor belt is also ensured.

Fig.4 *a) material division workplace vs. b) robotic arm*
Source: Own processing

The semi-finished product of the required length is transported to the milling workplace. The milling workplace consists of several milling devices, namely two mills. At this workplace, the largest downtime occurs within the entire production line of the puller body. The reason is the production capacity of these machines and the associated resetting of the machine after each milling. For capacity reasons, increasing the number of production equipment is one of the possible solutions to reduce downtime. For the distribution of production requirements, we chose to increase the number of production equipment to four pieces (see Fig. 5).

By increasing the number of production equipment, we also eliminated downtime due to resetting the machine after each operation. The required adjustment of the machine was created based on milling a constantly different surface of the part, for which constantly different parameters were set.

The machined part is moved to the next production equipment after each operation. Each machine is set up for a precise operation, so downtime due to resetting the machine is eliminated. At this workplace, we also considered the wear and tear of the cutting tools themselves.

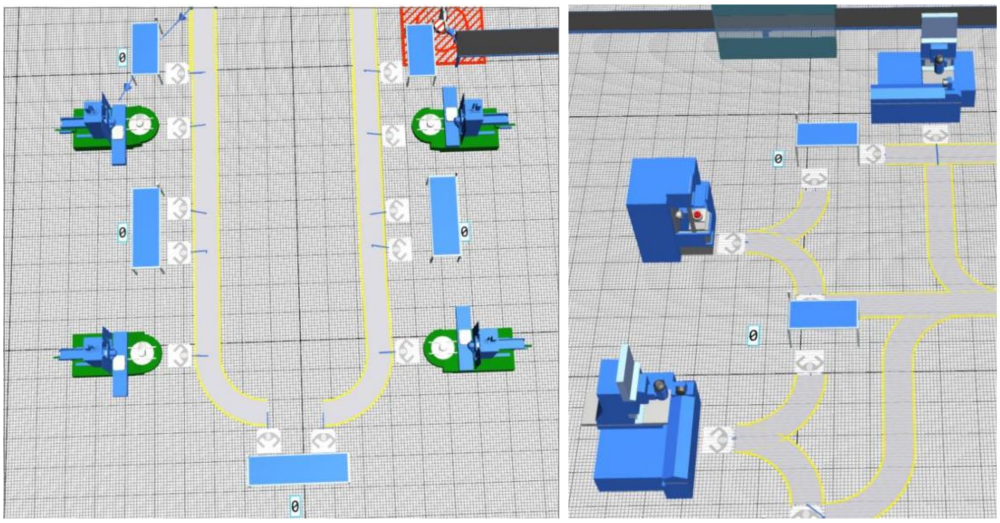
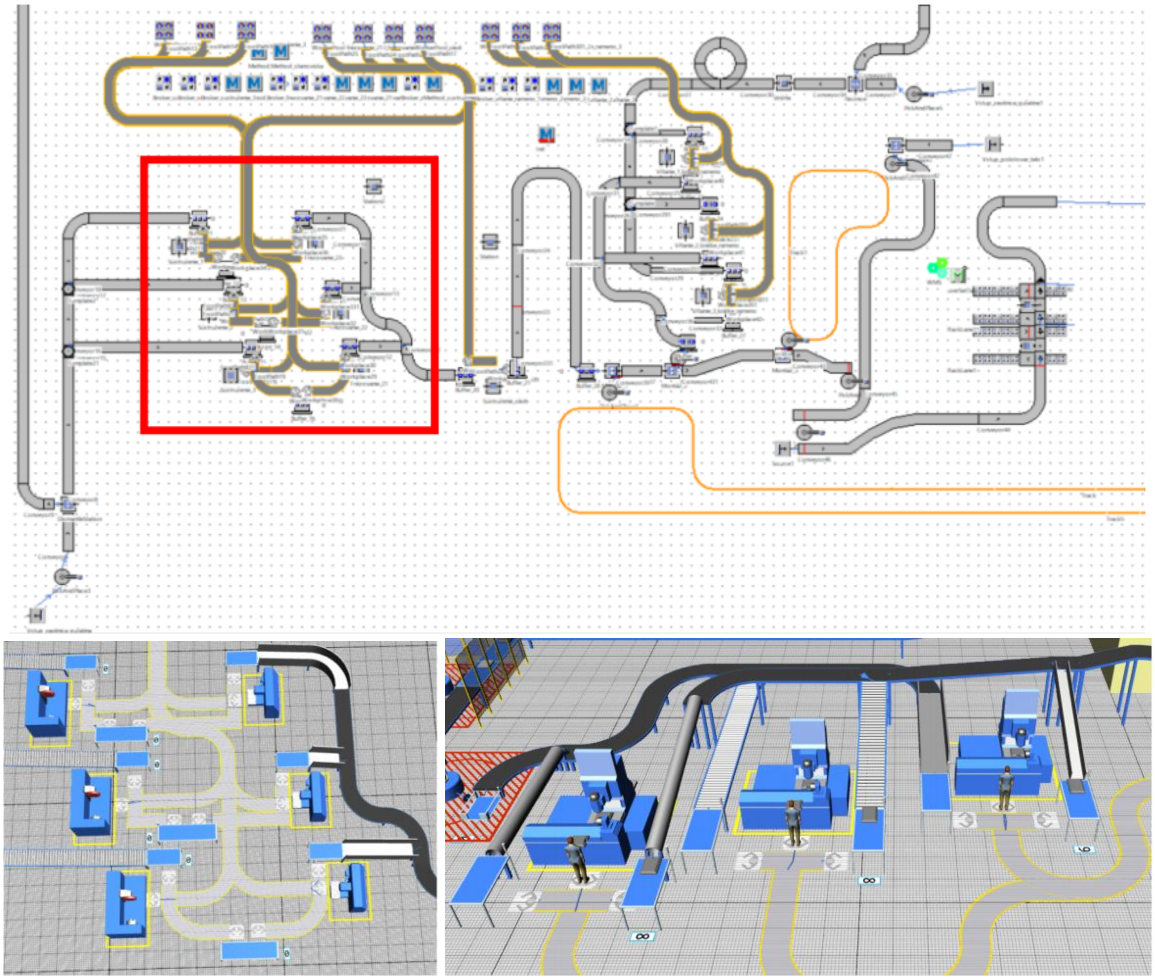


Fig.5 *Milling workplace in 3D*
Source: Own processing

Another technological step is drilling a hole for an internal thread in the center of the part and then drilling holes for attaching the arms using a screw with a hexagonal head. At this workplace, we made production more efficient and reduced downtime by adding one piece of production equipment, namely a column drill for cutting internal threads. Before the addition of this production equipment, there were downtimes at this workplace caused by the insufficient capacities of the production equipment. Most of the downtime was the time needed to change the tool from the drilling process to the threading process and vice versa. The newly designed workplace consists of a production facility for drilling a hole for thread cutting, a facility for thread cutting and a production facility for drilling three holes for mounting arms. At this workplace, transport between individual production facilities is ensured by the operators of these machines due to the small weight of the machined part and the short distance between the individual facilities. Before leaving the factory, the part stops for the degreasing process, the inspection process and travels further to the intermediate warehouse. A part is removed from the drilling and threading workplace, using a robotic arm on a conveyor belt. The part stops on this conveyor belt for the degreasing process. This process takes one minute and thirty seconds. After the process, the part proceeds to the inspection process. After quality control, the part goes to the intermediate warehouse. The finished part is transported to the robotic arm, which loads the parts onto an autonomous transport cart. A transport cart with a capacity of six pieces takes the finished product to the assembly workplace, which is in the adjacent production hall.



a) b)

Fig.6 *Second production hall (up) with workplaces in 3D a) turning and milling b) drilling*

Source: Own processing

The adjacent production hall, which was designed as a completely new production line, includes several processes. The first process is the production process of the spiral, the other processes are the production of the short arm and the assembly process. The manufacturing process of the spiral is marked with a red frame in Fig. 6. The production process of the tap consists of three production facilities for the turning process and three production facilities for the milling process. These workplaces work in the manner of production pairs, where after the turning process, the operator of the milling equipment takes the part and thus starts the milling process. After both of these processes, the spiral is ready for the assembly process.

After complete assembly, the part is ready for packaging and subsequent shipment. The packaging is ensured with the help of robots, which first place the parts in transport boxes, and then at the next workplace, these boxes are stored on a pallet, for better handling during expeditions. The packing process before shipping is shown in Fig. 7.

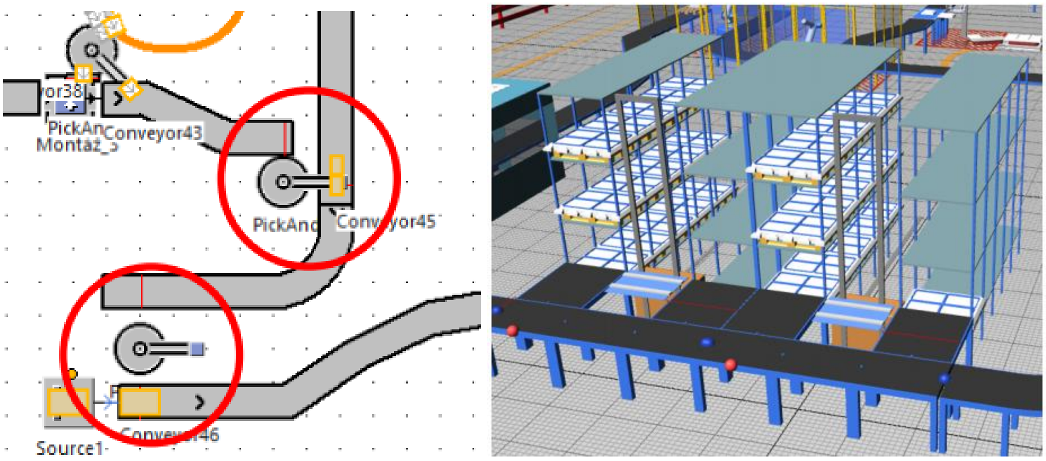


Fig.7 *Packaging workplaces and automatic filers*
Source: Own processing

The automatic stacker offers, within its possibilities, to simulate the removal time, the amount of removed goods, but also the time between individual pallets during removal. These options help to simulate the real storage process as best as possible, thus obtaining an almost perfect analysis of the storage unit.

Evaluation of designs and elements of digitization within simulated processes

The proposed changes or innovations that were used in the simulations helped to increase the number of manufactured pieces at individual workplaces, whether it was an increase in the number of production equipment or the automation of some processes. To evaluate and analyze the given process, we can see statistical data on the number of manufactured pieces during an eight-hour work shift at the milling workplace in the first production hall.

Simulation time:8:00:00.0000

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
Drain	telo	41:12.8696	92	12	34.17%	60.98%	4.85%	21.84%	

Cumulated Statistics of the Parts which the Drain Deleted

Fig.8 *Statistical data before the increase in the number of production facilities*
Source: Own processing

As you already see in Fig. 8 we can notice that before the increase in the number of production facilities, the number of pieces produced during one work shift was ninety-two pieces. These were two milling machines which, due to the heavy load and constant operation, required frequent maintenance.

Simulation time:8:00:00.0000

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
Drain	telo	22:26.3634	227	28	43.04%	48.04%	8.91%	33.42%	

Cumulated Statistics of the Parts which the Drain Deleted

Fig.9 *Statistical data after increasing the number of production facilities*
Source: Own processing

In Fig. 9, in turn, you can see the difference, which was reflected not only in the number of pieces but also in the average production time of the part. The average production time decreased by almost half, while the number of produced pieces was increased by one hundred and thirty-five pieces. It should also be noted that the proposed improvements are more or less theoretical, since everything that appeared to be a bottleneck was improved in the simulations, and that is why the result of the proposal is less than one hundred and fifty percent better than the original state. If all proposed changes were implemented, we could approach a relatively similarly high improvement. The proposed changes would be implemented gradually to make them more economically manageable.

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 often used in training operators of individual assembly equipment. This simulation is also ultimately connected to VR.

This type of virtual reality (Fig. 10) is one of the many ways in which the proposed improvements can be viewed from a different angle. The connection of this set is connected through applications, which are necessary for the device to be able to communicate with virtual reality. This technology is also one of several that was used in solving this work. To connect the simulation with VR, it is necessary to use an application from the manufacturer Oculus and the Steam application. The Oculus application is used to communicate virtual reality together with a computer. The Steam app handles communication between the simulated manufacturing process and the Oculus app.

Fig.10 *VR Headset Oculus Rift S, the Oculus app, Steam application*
Source: Own processing

One of the other technologies that can be used in the visualization of the production process or manufactured part is 3D printing. 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 (see Fig. 11).

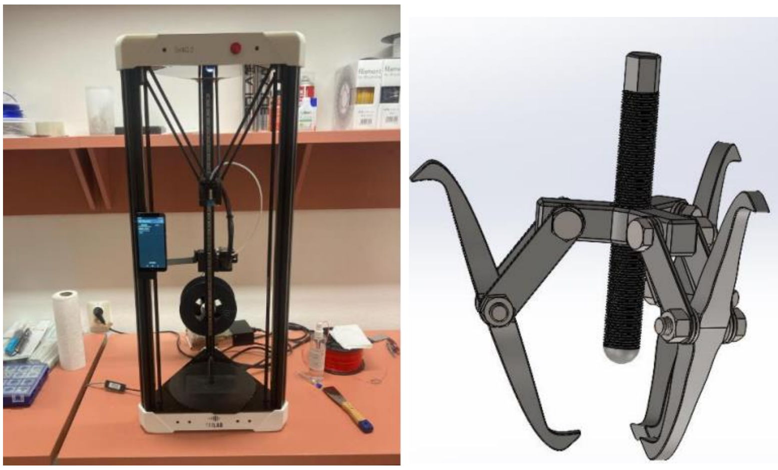


Fig.11 *Overall assembly of Puller and printing 3D printer in laboratory KPaDI*
Source: Own processing

3 CONCLUSIONS

Digital technologies make it possible to create a virtual environment of the entire plant, including buildings, distribution systems, transport and handling equipment, machines, equipment and workers. They are able to simulate the dynamic behavior of the system during the entire life cycle, thus achieving great cost savings associated with investment in real construction without virtual verification and visualization of solution variants. The technical basis for this purpose is made up of interconnected intelligent digital systems that create intelligent value chains of the entire product life cycle from the idea, through development, production, use, maintenance and repair to recycling. It is therefore easier for the manufacturer to ensure a higher degree of product customization.

Despite the high degree of diversification and differentiation of the product portfolio, it is possible to reduce costs and produce products more efficiently in this way. By connecting value chains between companies in the network, it is possible to optimize not only the production itself in a given company, but the entire value chain of the selected product. Since businesses work with information in real time, it is possible to respond flexibly to various changes, e.g. lack of raw materials in various stages of product realization, with an up-to-date overview of the condition and utilization of machines and equipment, it is possible to save resources and energy in production.

Digitization of industry and trade not only changes the value chains of companies, but also brings changes in business models and opens up possibilities for the creation of new jobs, it is also a perspective of increasing competitiveness for small and medium-sized enterprises, which are the engine of the economies of individual states. Digitization also brings with it the need to focus on IT security, personal data protection, introduction of uniform standards and norms for various industries.

The fourth industrial revolution is doomed to success if all parties involved (industry, science, research, politics and society) join this runaway train as soon as possible and build it on joint cooperation with the aim of achieving synergy. The main goal of research in this area is the development of integrated tools for industrial engineering and production adaptation with regard to configurability and partial autonomy of systems. Artificial intelligence in combination with the robotization of production is a prerequisite for the successful development of adaptive production, the implementation of intelligent production and non-production equipment and the construction of intelligent production systems.

Acknowledgement

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. VEGA 1/0508/22 „Innovative and digital technologies in manufacturing and logistics processes and system" KEGA 020TUKE-4/2023 "Systematic development of the competence profile of students of industrial and digital engineering in the process of higher education."

REFERENCES

Dujmešić, N., Bajor, I. and Rožić, T., 2018. Warehouse Processes Improvement by Pick by Voice Technology. *Tehnicki vjesnik - Technical Gazette*. 25(4), pp.1227-1233.

Duplakova, D., Hatala, M., Duplak, J., Knapcikova, L. and Radchenko, S., 2019. Illumination simulation of working environment during the testing of cutting materials durability. *Ain Shams Eng. J.*, 10, pp.161–169.

Ďurica, L., Gregor, M., Vavrík, V., Marschall, M., Grznár, P.. and Mozol, Š., 2019. A Route Planner Using a Delegate Multi-Agent System for a Modular Manufacturing Line: Proof of Concept. *Applied Sciences*, 9(21):4515.

Glova, J., Bernatik, W. and Tulai, O., 2020. Determinant Effects of Political and Economic Factors on Country Risk: An Evidence from the EU Countries. *Montenegrin J. Econ*., 16, pp.37–53.

Grznár, P., Gregor M., Mozol, Š., Krajčovič, M., Dulina, Ľ., Gašo, M. and Major, M., 2019. A System to Determine the Optimal Work-in-Progress Inventory Stored in Interoperation Manufacturing Buffers. *Sustainability*, 11(14):3949.

Grznar, P., Krajcovic, M., Gola, A., Dulina, L., Furmannova, B., Mozol, S., Plinta, D., Burganova, N., Danilczuk, W. and Svitek, R., 2021. The Use of a Genetic Algorithm for Sorting Warehouse Optimisation. *Processes*, 9, 1197.

Choque Encinas, G., Gomez Butron, J. and Ruiz-Ruiz, M. 2022. Three Simulation Cases of Automated Warehouse Picking Systems: A Comparative Analysis. In *1st Australian International Conference on Industrial Engineering and Operations Management*, https://doi.org/10.46254/AU01.20220171.

Knapcikova, L., Behunova, A. and Behun, M., 2020. Using a discrete event simulation as an effective method applied in the production of recycled material. *Adv. Prod. Eng. Manag.*, 15, pp.431–440.

Malkus, T. and Kozina, A., 2013. The features of negotiations within reverse logistics cooperation, Acta Logistica, 109(1), pp.111-119.

Pallai, B., Tamás, P. and Matyi, H., 2023. Order picking system evaluation usin RTLS method. *Advanced Logistic Systems – Theory and Practice*, 17(1), pp. 62-70.

Perkumienė D., Ratautaitė K. and Pranskūnienė R. Innovative Solutions and Challenges for the Improvement of Storage Processes. *Sustainability*, 2022, 14(17):10616.

Rosin, F., et al., 2022. Lean 4.0: typology of scenarios and case studies to characterize Industry 4.0 autonomy model, IFAC PapersOnLine 55-10, pp.2073–207.

Vegsoova, O., Khouri, S., Straka, M., Rosova, A., Kacmary, P. and Betus, M., 2019. Using Technical Means and Logistics Principle Applications to Solve Ecological Water Course Accidents. *Pol. J. Environ. Stud.*, 28, pp.3875–3883.

Warehouse Logistics Homepage, [online] Available at: <https://www.warehouse-logistics.com/en/definition-pick-by.html> [Accessed 23 Oct. 2023].

Williams, M., 2019. *Augmented Reality Supported Batch Picking System*.