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Reasons, benefits and challenges on the road to automated internal transportation

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Abstract: The article discusses the topic of available solutions related to process automation in companies. The focus is on intralogistics solutions, especially in the context of robotization of transport, using the example of automatically controlled vehicles. Industry 5.0, in addition to automation, pays attention to the human factor, stabilization and the environmental aspect, which is a challenge for many companies. Large organizations are automating their processes in an effort to increase flexibility and respond quickly to customer requirements. Wanting to match market requirements will be a particular challenge for small and medium-sized companies. The purpose of this article was to study and describe the case of a manufacturing company that decided to change the means of internal transportation - to automated. The article answers the research questions posed for what reasons companies are interested in intralogistics solutions and what challenges organizations face when implementing such solutions. The paper uses literature analysis and qualitative research in the form of a case study. The benefits to organizations of automating material handling are presented, which can be particularly beneficial information for the small and medium-sized business sector. A qualitative study conducted at a Polish automotive company shows that the implementation of AGV robots has significantly improved the efficiency of internal logistics, reducing the risk of accidents and increasing process systematization. These results confirm the growing interest in automation, which contributes to reducing costs, increasing revenues and meeting environmental requirements.

1 Introduction

The global market and e-commerce are contributing to the increasing demands of stakeholders, who expect high-quality products, delivered at the right place and time and at the lowest possible price [1]. Constantly changing consumer buying behaviour requires manufacturers to individualize production, variety, flexibility and shorter delivery times [2]. The aforementioned factors influence organizations' search for proven solutions to meet the expectations set by customers.

Logistics [3] focuses on how to use new technologies in a way that will increase the efficiency of an organization's operations. Modern solutions aim to improve the level of service so that logistics is characterized by faster response and better use of resources. Innovative solutions can support the transformation of businesses to meet Industry 4.0. or Industry 5.0.

Currently, companies are looking for solutions, investing in improvements that integrate processes and information flow [4,5]. The internal ordering and delivery system should allow for fluidity in the processes taking place, preventing waiting for material or even stopping entire lines. The speed of goods and information flows, maintenance of quality and efficiency of the logistics processes being carried out depend on the selection of appropriate equipment or software. The use of available technologies and devices in manufacturing companies is conditioned by the search for opportunities to improve internal processes. Organizations are also striving to digitize internal processes.

As the very definition of intralogistics indicates, such solutions should include and enable the organization, control, implementation and optimization of the internal flow of materials and information, as well as the handling of goods in both the business sector and public institutions. Currently, there is a strong emphasis on automation and digitization of processes that will take into account and facilitate human work and cooperation with robots [6]. For this, it is important to learn about intralogistics solutions, work on them, and point out good practices to others or suggestions for their improvement on the way to automating and digitizing the organization's operations.

Many recognize that the future of the logistics industry and its development is related to the application of innovative solutions to improve the quality of logistics services [7]. Taking into account the organization's pursuit of Industry 4.0, environmental aspects and meeting customer requirements, companies are striving to streamline internal processes. Using available equipment and systems, and implementing them correctly, enables a company to improve the flow of products and information. Industry 4.0 is a concept for the transformation of enterprises, related to the improvement of processes carried out internally using available technologies. Above all, it seeks to digitize and automate processes consequently facilitating the meeting of increasing market expectations [8]. Logistics for the Fourth Industrial Revolution focuses on how to use new technologies in a

way that will increase the flexibility, efficiency and productivity of an organization's operations.

The current fourth stage of logistics development offers the possibility of new business models, leading to standardization, reduction of material transportation and storage, thus creating added value in the processes taking place, including from an environmental perspective [9]. Today's logistics can be described as globally interconnected supply and value chains that are highly flexible and complex, thus underpinning modern supply and production concepts. Companies are looking for solutions to meet current challenges in the form of individualization, while optimizing production processes and costs [10]. The challenge is to apply available technologies and equipment in the field of Industry 4.0 [11]. Key technologies include intra-organizational logistics - called intralogistics.

Intralogistics refers to organizations whose activities involve the internal movement of materials. It is applicable to manufacturing companies or those involved in receiving goods and/or moving them between specific points. It includes subsystems such as warehousing, storage, picking and conveyor and transport systems [12]. In publications describing Industry 4.0 enterprises, intralogistics occupies a key position [13-15]. The implementation of available intralogistics solutions in the industrial world is playing an increasingly important role, due to the optimization and automation of processes and facilitating the flow of information and materials within a company [16]. Technological advances, emerging systems, and robots are designed to facilitate human work, automating it, eliminating the possibility of error and streamlining processes within the organization.

Given the advances in technology, widespread automation of production processes, increasing stakeholder demands and changing environments (pandemic, armed conflict, price increases, environmental aspects), companies face a huge challenge. It's hard to adapt to the changes taking place without knowing what solutions are available, or because they lack the necessary skills to sensibly select and apply something that can make work easier and allow further automation of processes. Manufacturing companies are also reluctant to share knowledge and experience with other entities. From a scientific and business perspective, there should be research and publication of works that can help other companies, especially small and medium-sized ones, on the road to automation and digitization of processes.

In connection with the topic addressed, two research questions were posed:

- for what reasons are companies interested in intralogistics solutions?
- what challenges do organizations face in implementing such solutions?

2 Literature review

The key areas of intralogistics are the use of appropriate infrastructure and storage systems for the implementation of internal logistics processes, management and the use of information technology. The right combination and alignment of solutions, promotes transparency of processes, information exchange and efficient execution of intended tasks. Intralogistics defines a future-oriented industry, representing all suppliers of conveyor technology, warehousing, systems, services and logistics software, enabling the organization, optimization and control of material and information flows in industry, commerce and public institutions [17]. It emphasizes the use of appropriate equipment, and thus the proper selection of suppliers of equipment, systems, software, along with accompanying services.

Currently there is talk of Industry 5.0 - focusing attention, in addition to automation, on the human aspect. The available digital solutions, modern technology is designed to facilitate work and/or cooperation with humans, placing human needs with the solutions of Industry 4.0. Additional aspects that Industry 5.0 pays attention to are the environment and resilience to crises - ensuring stability [18]. Automation of logistics processes, including intralogistics, is one of the key elements of Industry 5.0.

The concept of moving to the target level in intralogistics, is linked to the Internet of Things (IoT). Using automated and autonomous transport vehicles, control and communication between units is performed automatically through software. Being able to react in real time to changes in the surrounding environment, self-controlled entities increase the level of flexibility [19]. With the rapid development of IoT, networks based on wireless communication technologies are increasingly being used in Automated Guided Vehicle - AGVs [20].

Increased interest in intralogistics solutions can be observed. This trend is confirmed by a report published by the International Federation of Robotics which noted an increase in robot sales. According to the ISO 8373:2012 definition, a robot means "an automatically controlled, reprogrammable, multifunctional manipulator, programmable in three or more axes, that can be stationary or mobile for use in industrial automation applications." A distinction can be made between industrial and service robots. An industrial robot is "an automatically controlled, reprogrammable multifunctional manipulator programmable in three or more axes," while a service robot performs tasks for people or equipment excluding industrial automation applications.

One of the intralogistics solutions is automated robots (AGVs) or autonomous robots - (Autonomous Mobile Robots -AMR). In 2020, there was a 41% increase in sales of service robots compared to the previous year. The largest number (44,000 units) were applied to transportation and logistics, 34,000 to professional

cleaning, 18,000 in medical robotics, 15,000 in hospitality, and 7,000 in agriculture [21].

Among the market trends contributing to robot sales growth in the report are:

- localization and regionalization of supply chains (closer to the customer, avoiding problematic situations related to politics, security rules, possible impediments in supply chains),
- lower cost of ownership (growing supply of low-cost robots),
- individualization of production for a growing number of products (digitalization of production from order acceptance to delivery, robots influence the reduction of unit costs of mass production).

Advances in other technologies (technology trends) such as 5G, cloud computing, new machine vision, artificial intelligence (AI), are fostering the expansion of robot applications and improving their performance (speed and quality). Companies are implementing innovative solutions to match Industry 4.0 hoping to reduce production costs and wanting to gain a competitive edge. They are betting on automation, improving the quality of the products they offer and improving productivity [22].

Often in tandem with the use of automated or autonomous vehicles in internal transportation, reusable packaging is being introduced in companies. As IFR's research confirms, the use of reusable packaging reduces waste. Robotized production also has an impact on reducing the proportion of rejects, thereby reducing the carbon footprint.

The COVID-19 pandemic has also influenced an increase in robotization [23]. Companies have been forced to look for ways to become less dependent on the human factor. The global report "Intelligent Automation 2020" shows a significant increase in the percentage of organizations in 2020 that have begun implementing solutions based on intelligent automation. In this regard, 73% of surveyed companies took action in 2020, compared to only 48% a year earlier [24]. Disruption in the supply chain, the need for greater productivity in a secure environment as long-term effects of pandemics will require automation and digitization strategies from executives. Additionally, companies may be interested in intralogistics solutions wanting to delegate employees to more absorbing tasks [25].

According to a report by Interact Analysis, automation of warehouse operations is on the rise, and by 2027 more than a quarter (26%) will have some form of automation. This represents a significant jump from the 14% automation of warehouses a decade earlier. This is influenced by labor shortages, flexible manufacturing and the rise of e-commerce. Figure 1 shows the penetration of warehouse automation. As a result of the changes, manufacturing or warehousing companies should consider automation or enabling automated solutions in adjusting hall designs and/or layouts [26].

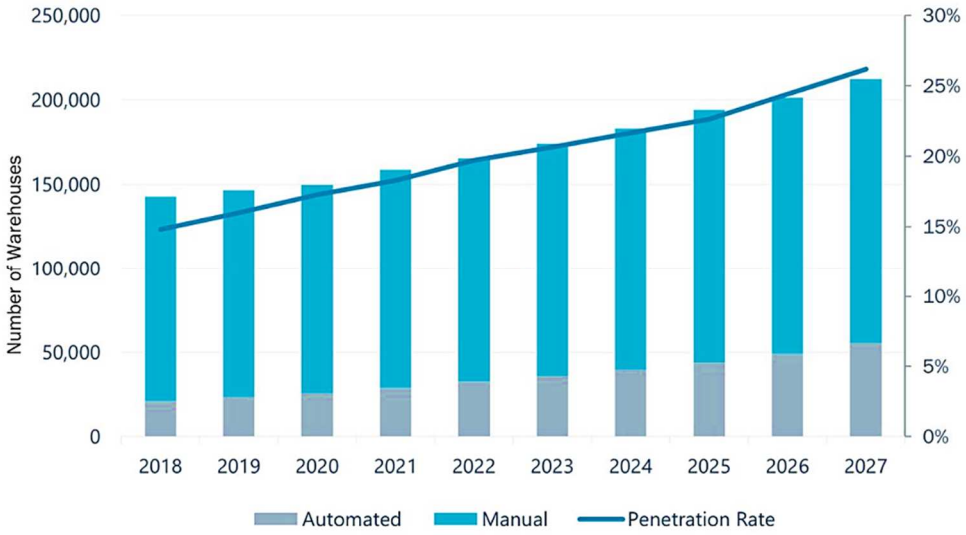

Figure 1 Warehouse automation penetration

The market for mobile robots (AGVs and AMRs) experienced strong growth in 2022. Interact Analysis forecasts the growth of automated (over 4 million) and autonomous vehicles through 2027, as shown in Figure 2 [27]. Revenue growth is projected to average 30-40% per year through 2027. Between 2022 and 2027, shipments of mobile robots will grow about 50% per year [27].

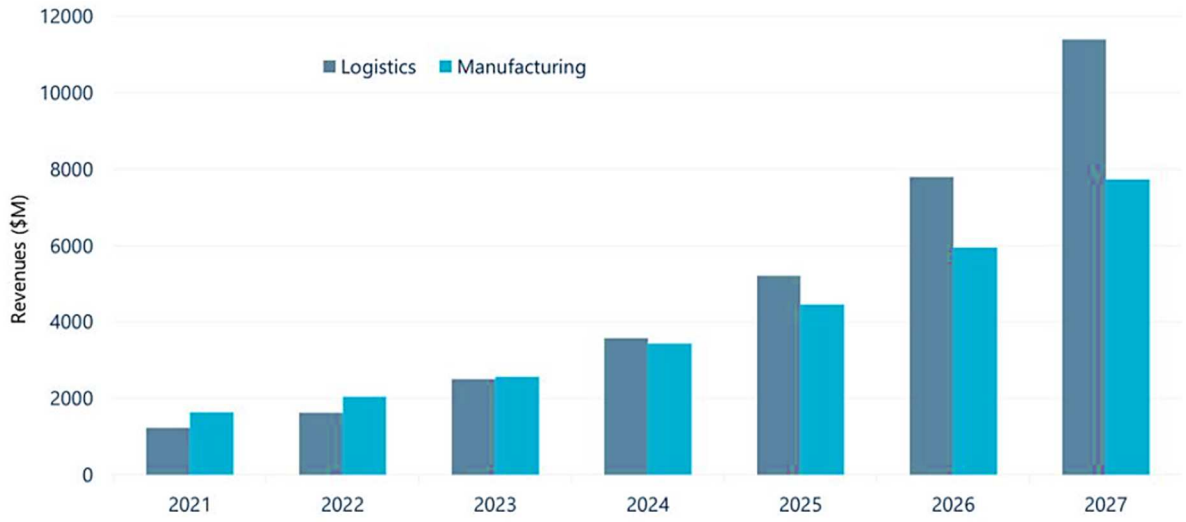

Figure 2 Mobile robot revenue forecast

Considering the cost-effectiveness of automation, interesting survey results are presented by Deloitte. Figure 3 shows the results obtained from a survey of 479 executives from various industries in 35 countries. Companies automate processes hoping to reduce costs, increase revenues, which, as the chart shows, have been increasing in recent years. The payback period is also increasing [28].

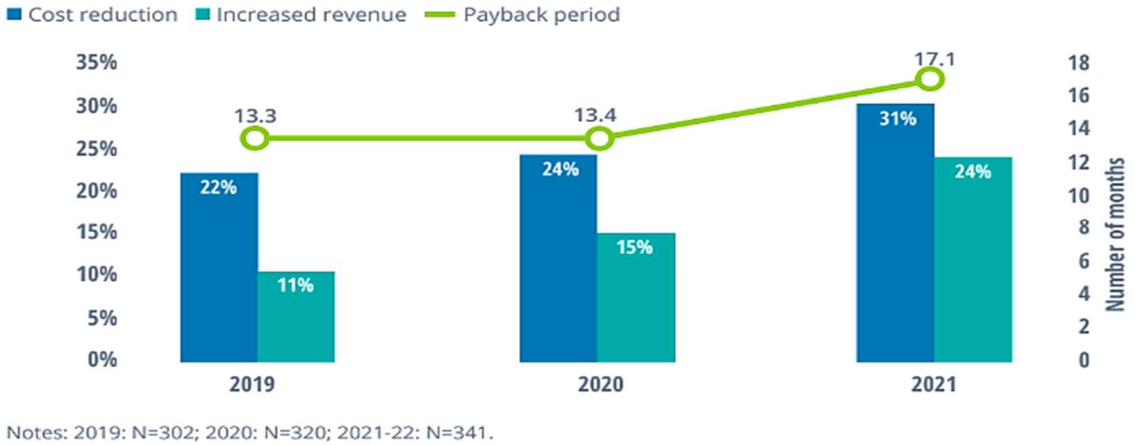

Figure 3 Enterprise automation - increased revenue, cost reduction and payback period

Taking into account the countries' policies on sustainable development, it forces the introduction of solutions that positively affect the work environment in entities. For the SME sector, there is a financial barrier related to the cost of purchasing such solutions [29,30]. Opportunities to subsidize the purchase and implementation of intralogistics solutions may prove effective in this regard. Therefore, it can be assumed that interest in the application of such solutions will grow depending on available subsidies or forms of support in the implementation of innovative solutions for small and medium-sized enterprises.

3 Methodology

Taking into account the topic addressed, which is the competitiveness of manufacturing companies, a qualitative study was chosen - a case study. Of the eight case studies conducted, one description is presented in the paper due to the same conclusions in the other companies, both small, medium and large in size. In addition, a quantitative study was conducted in Poland on a group of 35 companies that had automated internal transportation, and the conclusions were the same. The research was conducted in 2020-2021 at companies located in Poland. These were companies with both Polish and foreign capital. Due to the lack of generally available information on the type of technology and equipment used internally in companies, the results of the responding companies were relied on. It is worth noting that often this kind of information is a company secret, as it affects the preservation of the organization's competitiveness.

In order to achieve the set research questions, the method of analysis of available literature and reports on automation and digitization was carried out. The overarching goal is to explore and explain the phenomena taking place in enterprises. The search for answers to the set questions is made possible by using the inductive method applied by the qualitative study. The qualitative study was conducted in 2021 on the basis of an interview questionnaire.

4 Results and discussion

4.1 Case study

A qualitative study was conducted in a US manufacturing company located in south-eastern Poland. The company has approximately 100 employees. The means of internal transport used until now were forklift trucks, hand pallet trucks and electric trucks. The use of such a large number of vehicles also impacted on the lack of space on the production floor and increased the risk of workplace accidents involving forklifts driving on the production floor. These three main reasons led the company to find a different solution in this area.

The company, through reference visits to other organisations, tried to discern for itself the intralogistics solutions used. It also looked for examples of solutions at various industry events (e.g. intralogistics trade fairs), talking to representatives of companies offering such solutions, raising issues of potential benefits and risks.

The company, by conducting its own market research and studying the experience of other companies, identified several important aspects that led to the choice of AGV robots. It was found that this type of vehicle influences the aspect of improving work safety on the production floor, reducing the risk of accidents at work, which is important for a specific company with locations in different countries. Another aspect - the involvement of fewer people to implement internal transport. In 2016, two AGV robots were implemented in one of the branches. Before changing the means of internal transport, the company was obliged to change the layout of the hall and designate transport paths. A decision was also made to use reusable packaging in which components, products would be moved by AGV robots. An additional benefit of using such packaging is that it will not only be used internally, but also for transport from external suppliers. The robots purchased have lithium batteries, which means zero emissions for the environment.

The benefits of the implemented change were evident after the first week, and definitely influenced the systematization of internal logistics processes. The organization has a Kanban system, which works well in conjunction with the use of AGVs. One warehouseman was assigned to each of them to complete orders, deliver goods to the hall, and take empty containers to the warehouse. This organization of work made it possible to delegate the other people previously involved in handling internal transportation to other tasks.

AGVs make it possible to maintain safe working conditions, influence aesthetics, maintain good organization of the workplace, delivering the right quantities of products, at the right time, thus maintaining continuity of production. They make it possible to maintain transparency of the processes being carried out. Attached carts, on which components are transported, are more capacious compared to the previously used solutions. They make it possible to take a larger number of containers on a single trip, so that the necessary components are available on production lines, eliminating unnecessary waiting or downtime. By the same token, the efficiency of internal transport is significantly increased.

The company's biggest challenge has been to optimize transportation paths. The company is constantly optimizing internal flows, implementing appropriate solutions and reducing all costs. Simulation in a 3D environment was also considered, but such a solution, for the company, is a relatively expensive proposition, not necessarily allowing for a thorough testing of the new solution. In addition, the employees involved in the project to change the means of transportation, lack training, information or instructions for use, exchange of experience on issues related to all activities related to the preparation of the organization and information on what to look out for.

Unfortunately, not all employees saw the benefits of the improvements. On the part of the other production employees, there was negative feedback after the change in transportation means. Managers had to motivate, support the others to show the positive aspects from the use of AGVs. Often the change caused resentment and dissatisfaction among employees, but after about a month, it could be observed that employees got used to it and saw the benefits of the implemented improvements, especially in terms of improvements in order picking times at the warehouse.

The company has been richer in experience in handling this type of vehicle since 2016. Through the robotization of transportation, it is able to connect them to ERP system and monitor orders in real time. The transparency of the implemented processes has increased. The organization recognizes that this gives it an advantage over other companies in the market, and in the current situation it is more ready to automate other processes, or use autonomous robots, which is its next goal. According to the decision-makers of the company surveyed, the key is to gradually change the means of the vehicle, adapt the work, adjust the processes, and get the employees used to working with and operating robots. Once processes are stabilized, one can move on to the next challenges with emerging new technologies.

4.2 Discussion

The gradual automation of processes within the company is important. This includes transportation automation, real-time information exchange and product monitoring. Intralogistics solutions in the form of AGVs

and AMR vehicles make this possible. It is important to support the move toward automation on the scale of Industry 4.0 for small and medium-sized enterprises as well. They help achieve benefits for companies in the implementation of internal processes. They represent a positive change from the status quo. They allow real-time data exchange. This introduces some novelty on an enterprise scale. However, it is crucial to consider cyber security - network security so that unauthorized people do not have access to control such devices. The factors influencing the automation and use of intralogistics solutions by enterprises are shown in Figure 4.

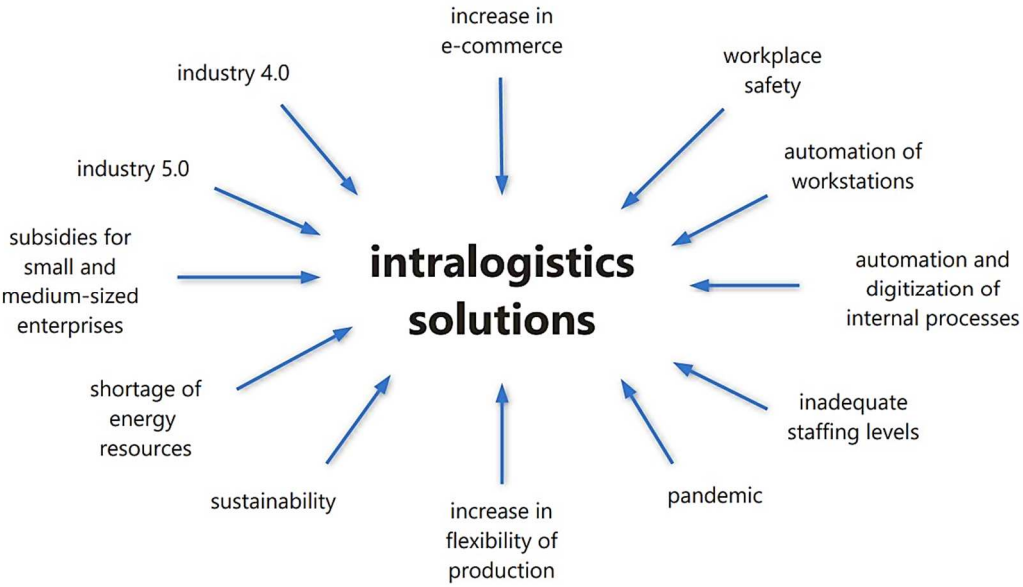

Figure 4 Factors influencing the automation of enterprises - application of intralogistics solutions

Automation and real-time information sharing present great opportunities for businesses, but also risks due to the possibility of cyber-attacks. Along with the application of modern solutions, attention should be paid to any security related to access to the enterprise information system [31]. Access to the system, the exchange of information on an ongoing basis allows processes to be carried out efficiently without human intervention. However, if an unauthorized person were to take control, robots and other devices could threaten the safety of employees.

An important issue in automating processes and implementing intralogistics solutions is the human factor. The case study described shows that people are often afraid of change, of stepping out of their comfort zone. They need time to get acquainted with something new and different. In the age of digitization and automation, it is crucial to raise the competence of employees, familiarize them with available solutions and teach them how to work with new technologies. There is a reason for the emergence of the concept of Industry 5.0 - which emphasizes the focus on the human being, who is supposed to operate and cooperate with the new technology, and who is supposed to be facilitated by it. In addition, the post-pandemic experience, the turbulent environment and the changes that are currently taking place are not supposed to affect the processes taking place in companies, only their design and operation are supposed to be immune to them. Additionally, all actions taken are to consider the impact on the environment [32].

Intralogistics solutions in the form of automated or autonomous robots allow the use of environmentally friendly batteries and the way they are powered (e.g., solar energy), the use of reusable packaging, relieving the burden on human resources and delegating them to more absorbing work, automating processes and combining them with other solutions, which facilitates real-time tracking of task execution, thus allowing flexible production.

Important aspects in raising the level of automation and matching intralogistics solutions to enterprises [33] will be the exchange of experience and the popularization of research results on the characteristics of the transport solutions under study. Larger entities, working with other foreign companies, have the opportunity to follow good examples. However, despite this, the development of good practices internally is often achieved by trial and error.

Manufacturing companies are reluctant to share the experience they have developed. Each of them is concerned with being competitive. However, a general characterization of the topic could prove to be a helpful solution for companies in various industries, aiming at overall economic development. Process innovations bring beneficial changes within an organization. They create an environment for the emergence of new opportunities for

improvement, the application of available technical or technological solutions.

5 Conclusions

Increasing awareness and presenting the essence of intralogistics solutions can influence the decisions of other organizations. Automation and digitization of processes in line with Industry 4.0 or 5.0 focuses on the implementation of solutions within the organization. This is especially important in an era of increasing market demands, automation of processes in which intralogistics is a central point. The challenge of transport automation, the benefits and their impact on the organization may be particularly beneficial in the exchange of experiences of enterprises, especially from the small and medium-sized enterprise sector. Considering the statistical data, an increase in robot sales is evident. There is a lot of talk about automation, the digitization of production, the replacement of human labor with robotic work. Automation will continue, so it is worth popularizing the experiences of other enterprises to improve available technologies and solutions with a view to working with humans.

The described case study shows that companies are not always aware of the available solutions and what benefits they can introduce for themselves and the environment. Considering the organization's environment, companies are reluctant to share their experiences, given the increasing competition. The example given can be helpful in presenting a practical take on the application of a selected solution that fits into Industry 4.0 solutions. It not only has a positive impact on the organization, on the processes taking place in it, on the safety of employees' work, but also has a positive impact on the environmental aspect (solid packaging, lithium-ion batteries). An additional incentive may be European Union funds, grants for innovative solutions, which may include intralogistics solutions. The benefits presented in the case study described, can contribute to the justification of the project or grant to implement solutions that significantly improve the functioning of internal processes.

The described case study presents not only a positive impact on internal logistics, but also on other areas of the organization. The use of AGVs has forced a change from single-use packaging of transported materials to reusable packaging. As a result, the company has less waste, and the packaging used is used in the warehouse, internal and external transportation. Another positive environmental impact is the batteries used to power the automated vehicle. The company uses the Kanban system, which works perfectly with the automatic delivery of orders to individual stations. Another benefit is the overcoming of the Man-Machine barrier. Employees can learn how to work with the automated vehicle, which will affect faster adaptation to work with more automated factories in the future. Automated transportation will ease the burden of employee involvement, so companies can delegate people to more demanding tasks.

The example given has its limitations. The benefits and organizational impacts described will generally be more or less the same in manufacturing companies. However, due to the increasing importance and application of artificial intelligence and IoT integration, research should be constantly conducted on their impact on the implementation of logistics processes and the prediction of resource demand. An important issue is cybersecurity and data security research to protect enterprises from potential cyberattacks. After the COVID-19 pandemic should constantly study the adaptation of new technologies in response to changing working conditions and supply chains. Another important issue is to study the impact of automation on the employment, qualification and safety of workers.

References

[1] SHI, X., TANG, J., DONG, C.: Should a domestic firm carve out a niche in overseas markets? Value of purchasing agents, *European Journal of Operational Research*, Vol. 300, No. 1, pp. 85-94, 2022. https://doi.org/10.1016/j.ejor.2021.07.019

[2] ELMARAGHY, H., SCHUH, G., ELMARAGHY, W., PILLER, F., SCHÖNSLEBEN, P., TSENG, M., BERNARD, A.: Product variety management, *CIRP Annals*, Vol. 62, No. 2, pp. 629-652, 2013. https://doi.org/10.1016/j.cirp.2013.05.007

[3] WINKLER, H., ZINSMEISTER, L.: Trends in digitalization of intralogistics and the critical success factors of its implementation, *Brazilian Journal of Operations and Production Management*, Vol. 16, No. 3, pp. 537-549, 2019. https://doi.org/10.14488/BJOPM.2019.v16.n3.a15

[4] DOBNI, C.B.: The relationship between an innovation orientation and competitive strategy, *International Journal of Innovation Management*, Vol. 2, No. 14, pp. 331-357, 2010. https://doi.org/10.1142/S1363919610002660

[5] CHO, H.J., PUCIK, V.: Relationship between Innovativeness, Quality, Growth, Porfitability, and Market Value, *Strategic Management Journal*, Vol. 26, No. 6, pp. 555-575, 2005. https://doi.org/10.1002/smj.461

[6] URRU A., WEZEL, J.P., BONINI, M., ECHELMEYER, W.: *Dynamic Resource Allocation Considering Ergonomics in Intralogistics*, 25th IEEE International Conference on Intelligent Engineering Systems, pp. 81-88, INES 2021. https://doi.org/10.1109/INES52918.2021.9512930

[7] SCHUHMACHER, J., HUMMEL, V.: *Development of a descriptive model for intralogistics as a foundation for an autonomous control method for intralogistics systems*, 8th Conference on Learning Factories 2018 - Advanced Engineering Education & Training for Manufacturing Innovation, Procedia Manufacturing, Vol. 23, pp. 225-230, 2018.

[8] GÜNTHER, W., HOMPEL, M.: *Internet der Dinge in der Intralogistik*, Springer, pp. 9-10, 2010. (Original in German)
[9] ABHAY, G.K., HASAN, A.M.: Automnomus and IoT-driven intralogitics for Industry 4.0 warehouses: A thematic analysis of the literature, *Transportation Journal*, Vol. 63, No. 1, pp. 42-61, 2024.
[10] ABELE, E., ANDERL, R., METTERNICH, J., WANK, A., ANOKHIN, O., ARNDT, A., MEUDT, T., SAUER, M.: Effiziente Fabrik 4.0 – Einzug von Industrie 4.0 in bestehende Produkktionssyteme, *Zeitschrift für wirtschaftlichen Fabrikbetrieb*, Vol. 110, No. 3, pp. 150-153, 2015. https://doi.org/10.3139/104.111293 (Original in German)
[11] SANIUK, S., GRACZYK, M., KUŁYK, P.: *Challenges of logistics in the concept of Industry 4.0*, Carpathian Logistics Congress CLC 2018, Dec. 3rd-5th 2018, Tanger, Prage, Czech Republic, pp. 792-792, 2018.
[12] GUDEHUS, T.: *Logistik: Grundlagen-Strategien-Anwendungen*, Springer-Verlag Berlin Heidelberg, 2010. (Original in German)
[13] PEUKERT, S., TREBER, S., HAEFNER, B., LANZA, G.: Process model for the successful implementation and demonstration of SME-based industry 4.0 showcases in global production networks, *Production Management, Production Engineering*, Vol. 14, pp. 257-288, 2020.
[14] KURSCHL, W., PIMMINGER, S., SCHÖNBÖCK, J., AUGSTEIN, M., ALTMANN, J.: *Using Mixed Reality in Intralogistics – Are we ready yet?*, International Conference on Industry 4.0 and Smart Manufacturing, Procedia Computer Science, Vol. 180, pp. 132-141, 2021.
[15] ANDERL, R., PICARD, A., WANG, Y., FLEISCHER, J., DOSCH, S., KLEE, B., BAUER, J.: *Guideline Industrie 4.0: guiding principles for the implementation of Industrie 4.0 in small and medium sized businesses*, VDMA Forum Industrie, Vol. 781, pp. 1-31, 2016.
[16] FERNANDES, J., BABTISTA, A., SILVA, F.J.G., CAMPILHO, R.D.S.G, PITNO, G.F.L.: *Intralogistic and industry 4.0: designing a novel shuttle with picking system*, 29th International Conference of Flexible Automation and Intelligent Manufacturing (FAIM2019), June 24-28, 2019, Limerick, Ireland, Procedia Manufacturing, Vol. 38, 2019.
[17] WANG, G., ANDERL, R.: *Generic Procedure Model to Introduce Industrie 4.0 in Small and Medium-sized Enterprises*, Proceedings of the World Congress on Engineering and Computer Science, Vol. 2, October 19-21, San Francisco, USA, pp. 971-976, 2016.
[18] GRABOWSKA, S., SANIUK, S., GAJDZIK, B.: Industry 5.0: improving humanization and sustainability of Industry 4.0, *Scientometrics*, Vol. 127, No. 6, pp. 3117-3144, 2022. https://doi.org/10.1007/s11192-022-04370-1
[19] PRASSE, H., NETTSTRAETER, A., HOMEP, M.: *How IoT will change the design and operation of logistics systems*, International Conference on the Internet of Things (IOT), pp.55-56, 2014.
[20] SONG, Y., YE, F.R., ZHOU, L., YANG, X., HE, Z.: Applications of the Internet of Things (IoT) in Smart Logistics: A Comprehensive Survey, *IEEE Internet of Things Journal*, Vol. 8, No. 6, 4263, pp. 4250-4274, 2021. https://doi.org/10.1109/JIOT.2020.3034385
[21] IFR: *IFR International Federation of Robotics, Press Conference World Robotic 2021*, 28 Oct 2021, [Online], Available: https://ifr.org/standardisation [25.10.2023], 2021.
[22] BATORSKA, S.: Smart Industry Polska 2018. Raport o innowacyjności MŚP, *Automatyka*, Vol. 6, pp. 93-100, 2018. (Original in Polish)
[23] AHMED, T., KARMAKER, C.L., NASIR, S.B., MOKTADIR, M.A., PAUL, S.K.: Modeling the artificial intelligence-based imperatives of industry 5.0 towards resilient supply chains: A post-COVID-19 pandemic perspective, *Computers & Industrial Engineering*, Vol. 177, No. March, 109055, pp. 1-12, 2023. https://doi.org/10.1016/j.cie.2023.109055
[24] DELOITTE: *Automation with intelligence: Pursuing organization-wide reimagination*, Deloitte University EMEACVBA, Diegem, 6, 2020.
[25] HASIJA, K.G., DESAI, K., ACHARYA, S.: A*rtificial Intelligence and Robotic Automation Hit by the Pandemic: Reality or Myth*, Tyagi, P., Chilamkurti, N., Grima, S., Sood, K. and Balusamy, B. (Ed.) *The Adoption and Effect of Artificial Intelligence on Human Resources Management, Part* B (Emerald Studies in Finance, Insurance, and Risk Management), Emerald Publishing Limited, Leeds, pp. 127-147, 2023. https://doi.org/10.1108/978-1-80455-662-720230009
[26] SCRIVEN, R.: *26% of Warehouses to be Automated by 2027*, [Online], Available: https://interactanalysis.com/insight/26-of-warehouses-to-be-automated-by-2027 [11 Oct 2023], 2023.
[27] SHARMA, A.: *Mobile robot shipments grow by 53% in 2022*, [Online], Available: https://interactanalysis.com/insight/mobile-robot-shipments-grow-by-53-in-2022 [11 Jun 2023], 2023.
[28] SIKORA, S., BORAH, P.R., IYER, A.: *Automation with intelligence*, Deloitte Insight, [Online], Available: https://www2.deloitte.com/content/dam/Deloitte/de/Documents/Innovation/Automation_Intelligence.pdf [20 Nov 2023], 2023.
[29] OSOLIŃSKI, W., KOLIŃSKI, A., KILIC, Z.: *Concept of communication integration for automated production processes regarding logistics 4.0*, In: Adamczak, M. et al., Digitalization of Supply Chains,

Spatium, Radom, pp. 85-100, 2019. https://doi.org/10.17270/B.M.978-83-66017-86-3.7

[30] COOMBS, C.: Will COVID-19 be the tipping point for the Intelligent Automation of work? A review of the debate and implications for research, *International Journal of Information Management*, Vol. 55, No. December, 102182, pp. 1-4, 2020. https://doi.org/10.1016/j.ijinfomgt.2020.102182

[31] HAJDA, J., JAKUSZEWSK, R., OGONOWSKI, S.: Security Challenges in Industry 4.0, PLC Systems, *Applied Sciences*, Vol. 11, No. 21, 9785, pp. 1-26, 2021. https://doi.org/10.3390/app11219785

[32] ADITYA, A., EURESTI, D., LUNA, S., ANKOBIAH, W., LOPES, A., EDINBAROUGH, I.: State of Industry 5.0—Analysis and Identification of Current Research Trends, *Applied System Innovation*, Vol. 5, No. 1, 27, pp. 1-14, 2022. https://doi.org/10.3390/asi5010027

[33] LI, M., HUANG, G.Q.: Production-intralogistics synchronization of industry 4.0 flexible assembly lines under graduation intelligent manufacturing system, *International Journal of Production Economics*, Vol. 241, No. November, 108272, 2021.

Review process
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