TECHNOLOGICAL AND ORGANIZATIONAL INNOVATION IN WAREHOUSING PROCESS – RESEARCH OVER WORKLOAD OF STAFF AND EFFICIENCY OF PICKING STATIONS

Izabela Kudelska[1]*, Rafał Niedbał*[2]

[1] Poznan University of Technology, Faculty of Engineering Management, Poland, ORCID: 0000-0002-8717-4315, izabela.kudelska@put.poznan.pl;

[2] Czestochowa University of Technology, Faculty of Management, Poland, ORCID: 0000-0001-6898-8818, rafal.niedbal@pcz.pl.

Abstract: *In their response to the necessity to meet the demands of customers, the enterprises are forced to reduce the time of order delivery. Today, almost every enterprise has its own warehouse facilities or outsources warehouse processes. Therefore, the contemporary warehouses play a significant role in production and service networks. The maintenance of high efficiency of warehouse processes determines the competitive functioning of enterprises. Continuous progress in this area sets the pace for these changes. Nevertheless, despite of the desire to reduce costs while increasing the efficiency of the warehouse process, you cannot forget about employees. In addition to efficiency and the level of generated costs, a warehouse employee is one of the factors that not only affects the shape of the logistics system in an enterprise, but also affects all links in the supply chain. This study is intended to research the impact of technological and organizational innovation implemented in the warehousing process on the efficiency of picking processes and staff workload on picking stations. The research was performed with warehouse simulation models developed in FlexSlim 3D Simulation Software. The simulated warehouses represent the warehouses in B2C (Business to Customer) logistics. They are about the layout of bag-type warehouse and the size and shape of the assortment varies. The size of storage zone is the same for all three warehouses. In these warehouses the assortment is arranged randomly. For each model, several simulations have been performed. The conducted research has shown that the results of technological and organizational innovation implemented in the warehousing process should be in general evaluated positively. Both the warehouse productivity and the picking process efficiency increased. The staff workload decreased, which is reflected in greater work comfort for a man and which supports implementation of control activities. However, it should be noted that implementation of the technological and organizational innovation in the warehousing processes adopted in various enterprises changes the labor market, thus it is possible that some problems with maintaining current employment levels will occur.*

Keywords: *Warehousing, order-picking, automation, simulation, innovation, labor productivity.*

JEL Classification: *C63, D24, O33, J21.*

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Introduction

Contemporary enterprises operate on a highly competitive market. Turbulent environment and individual needs of consumers cause that plenty of enterprises cooperate with other organizations within a supply chain. The above conditions determine the need for the managers to make effective logistics decisions.

Over the last few years, the enterprises faced some high cost pressures in numerous industries. Therefore, they started reorganizing and improving logistics process in order to allow further reduction in operating expenses. A demanding customer and shorter economic life-time increase the demand for flexible and fast deliveries (Grosse & Glock, 2013). Enterprises introduce changes and seek saving also in the area of warehousing.

Warehouses pose some important links in an enterprise. They determine places where goods are deposited and stored in a given supply chain link, until they are released. Warehouses as defined by Shah and Khanzode (2017) are a kind of buffer which serves to store goods between processes carried out in enterprises and between the enterprises themselves, thus allowing continuous movement of goods. Today's warehouses should be characterized with quick implementation of warehousing processes, first of all the picking and warehouse issue stages.

Enterprises invest in new technologies and digitalization which leads to increased automation in a warehouse. Robots start to do such operations as packing or shelf-stacking. However, the use of automation and robotization in warehousing processes in contemporary enterprises should be generally assessed as unsatisfactory. An example of such a state of affairs may be the research results obtained by St. Onge Company from the USA – dealing with engineering consultancy (Bonkenburg, 2016). The research carried out by the company among its own customers confirm a low degree of automation and robotization in warehousing processes. As many as 80% of warehouses do not use any process automation. There is mechanization in 15% of warehouses – these are first of all solutions adopted in the field of conveyors, sorters and equipment that support the picking of the ordered goods. Only 5% of the warehouses are automated, but they still have employees hired to hold the key functions. Examples of use of automation and robotization in warehousing processes are: unloading and loading robots, transport warehouse robots, stationary and mobile warehouse robots. Warehouse automation systems are most often based on implementation of tools allowing for remote control of warehouse vehicles (Sosnowski, 2017).

Along with the concept of the warehousing processes automation, new solutions support the implemented processes (e.g. introduction of cooperating robots) – which in the long run also results in a return on invested capital, elimination of bottlenecks, etc. Improperly implemented storage processes may result in inefficient use of the organization's resources. This may generate some delays in deliveries to the client and as a result leads to a deteriorated customer service level.

Managing warehouse facilities and processes in the warehouse is a big challenge for managers. This requires skills and trade-offs between increasing throughput and lowering labor costs, increasing picking speed and accuracy of tasks.

The purpose of this study, which is to attempt to answer the below questions, was formulated while realizing the importance of the warehousing processes and their automation for an enterprises and whole supply chains, and taking into account the results of automation for enterprises and the society:

1. *Will the introduction of a technological and organizational innovation in a warehouse improve the picking process efficiency?*
2. *How will the staff workload and demand for workers change after introducing the technological and organizational innovation in the picking process?*

Research of scientists covers primarily the area related to the speed of introduced innovations, or covers the area related the impact of innovations on the company. Whereas our research involves the impact of innovation on warehouse workers in the picking process – one of the most labor-intensive and time-consuming warehouse processes. This knowledge is important because the implementation of technological and organizational innovations in this area is not always positive.

This paper presents the results of simulation tests on the efficiency of picking station and staff workload within the picking process, along with a discussion over the effects of introducing the organizational and technological innovation in a warehouse. It contributes to the literature on implementation of innovation in a warehousing process.

The paper is composed of three chapters. Chapter 1 provides an overview of related literature. Chapter 2 clarifies the way which the warehouse models were developed, and the simulation tests were carried out in. The next chapter describes the results from the experiment, presents the discussion on the effects of implementing the innovations and attempts to answer the research questions. The last chapter sums up the paper and presents some suggestions on further research work.

1. Literature Review

Supply chain management in a global dimension is becoming important an issue for numerous enterprises. It covers the interests of suppliers all over the world as well as the focus on a local, domestic and international consumer. One process that exerts some significant impact on product quality, customer service level and global logistics costs is the warehousing process.

It includes not only physical storage but also receiving, picking and issue of goods as well as processing of necessary information regarding the warehoused goods. The warehousing also covers some organizational aspects, material carriers and equipment.

One of the most labor-intensive and time-consuming warehouse processes is picking (Franzke et al., 2017). De Koster (2007) defined the picking process as a procedure of collecting SKUs from storage areas with an intention to deliver customers' orders.

If order picking is not adequately organized, improper or damages SKUS are chosen, then implementation of the order may have negative impact on the customer satisfaction (Gue, Meller, & Skufca, 2006; Parikh & Meller, 2009). Efficient picking processes are therefore a prerequisite for an efficient supply chain (Chen et al., 2013; Franzke et al., 2017).

A lot of work is done manually in a warehousing process. A traditional warehouse worker spends most of the time walking around a warehouse or seating while driving a means of internal transport. Moving around the warehouse they can cover a total of up to 25 km during a shift (Kudelska & Pawłowski, 2019). Hence, the issues related to the picking process are still relevant and widely discussed by researchers and enterprises.

According to the research by Grosse, Glock and Neumann (2017), the greatest number of articles in this areas were recorded in the Journal of Production Research, where 30 papers of this kind were published. These topics were also raised in such magazines as: European Journal Operational Research, IIE Transactions, Computers & Industrial Engineering. The notions considered in the above-mentioned works first of all included the research on designing and managing the picking process (Kudelska & Pawłowski, 2019).

Gu, Goetschalckx and McGinnis (2007, 2010) provided a broad review and assessment of the picking processes performance – including route allocation. De Koster, Le-Duc and Roodbergen (2007) presented a planning approach that can ensure efficient warehouse process management.

One of the most significant topics raised in the literature is development of planning procedures that will help reduce the travel time of a worker picking an order. Strategies for 'S-shape' and 'Return' have been developed (Petersen & Aase, 2004; Theys et al., 2010). Petersen, Siu and Heiser (2005), De Koster, Le-Duc and Roodbergen (2007) and Gu, Goetschalckx and McGinnis (2010) explored how to deploy goods to reduce the time needed for order picking. The criterion of demand frequency was used in the above cases. In the meantime, Glock and Grosse (2012) considered the correlation of demand in allocation of products. Some authors like: Kovacs (2011), Chackelson et al. (2013), or Battini et al. (2015, 2016) used the class-based method of storage, which divides products into groups, which are afterwards stored in dedicated areas of the warehouse. However, storage in a given area is random.

Also the indicators of efficiency measurements in a warehouse were researched. In their paper, Staudt et al. (2015) pointed to four basic indicators of efficiency in a warehouse, namely the time, quality, cost of labor and efficiency.

Another important researched aspect in a warehouse is inventory control and proper warehouse management which is reflected in the enterprise's success. It is therefore so important to measure the warehouse efficiency based on organizational strategies. Effective performance measurement systems go beyond the history of reporting and improve future operations (Gunasekaran, Marri, & Menci, 1999).

The Lean topics were also undertaken in the field of warehousing. Ackerman (2007) studied the storage process from a Lean perspective. Sharma and Shah (2016) presented the Lean Manufacturing model for performance assessment. Shah and Khanzode (2017) presented an approach to support the Lean Thinking strategy in designing rules for allocating heterogeneous loads in order to improve material flow.

Furthermore, an analysis of the literature of the subject also revealed some topics related to technological and organizational innovation. Baker and Halim (2007) raised the notion of exploring the warehouse automation implementations (costs and flexibility), using the survey questionnaire and interviews, but only with a selected group of enterprises. E-commerce warehouses also use AGVs (Automated Guided Vehicle). Such solutions have some restriction related to space or traffic management (collisions, congestion). Therefore, Yan, Zhang and Qi (2017) proposed some control principles and strategies to improve the efficiency of the AGV system. Innovative solutions for the use of robots in a warehouse were also presented in the article by Bogue (2016). These robots have a function of collecting shelves and navigate autonomously. As for now, mobile robots play an important roles in picking activities – they navigate to a certain location, lift a given object and transport it to the packing area. QR (Quick Response) codes are used for this purpose. Such codes are located on the ground in strategic locations of the warehouse where a proper shelf must be collected, and thus the desired objective can be achieved. The work focuses on developing an efficient algorithm for planning a robot path using a QR code (Teja & Kumar, 2018; Enrigh & Wurman, 2011; Wurman, D'Andrea, & Mountz, 2008).

The literature studies prove that the discussed topics are mainly related to development of methods that reduce the transport time, distance and storage time. The work include supporting managerial decisions on financial effectiveness and performance of a warehouse. There are also issues related to the automation of warehouse processes. However, the interest in implementing automation into the warehouse is usually related only to the reasons for its application (improvement in product/service quality, increased storage capacity, improve customer service level, improve customer quality, increase in the number of served customers). The results of implementations of innovations are treated in general terms, often analyzed through the prism of increasing the picking process efficiency.

The human factor is considered in a narrower scope as the main aspects of deliberations and research on effects of technological and organizational innovations implemented in the picking process. Works by Calzavara et al. (2019) and by Glock et al. (2019) are worth stressing here as these authors considered not only the economic but also ergonomic objectives in their research. In turn, Vujica Herzog et al. (2018) conducted a study on the effects of the use of smart glasses during the order picking process.

The contemporary technologies and innovations implemented in the area of manufacturing and warehousing process allow for both process activities capable of supporting the sensual and intellectual operations of a worker, and actuation operations capable of supporting and replacing the worker's energetic functions (Olszewski, 2016). Research in the field of innovation includes examines the relationship between external knowledge sourcing and firm innovation efficiency (Asimakopoulos, Revilla, & Slavova, 2019). Was examined the impact of foreign companies on innovative companies, e.g. in the UK (Xia & Liu, 2018) and was examined what and to what extent impact to innovation radicalness and innovation speed (Behrens & Patzelt, 2018).

However implementation of the technological and organizational innovations in the mentioned area may have negative social impact on the workers. They are related to the issue of reducing the employment – so-called technological unemployment (Rąb & Rąb, 2016). Reduction in the number of jobs may appear not only as a result of workers being replaced by machines. It is enough that machines support workers in an increasingly broader scope, improving their work performance. This fact alone makes other employees less needed (Niedbał, 2018). There is one simple argument for such solutions from the perspective of an employer – it is more cost-effective, cheaper.

Automation of the warehousing and production processes is adequate for routine operations that are carried out systematically, in particular by low-skilled workers. In the case of medium- and high-skilled workers such a situation may emerge as well, but only when human actions become routine. Work features that contribute to replacement of a man by machines and automated systems include repeatability, algorithmization, demand for high physical strength, work in hazardous conditions. While the features that are difficult to replace are: originality, creativity, social skills, requirement for motor coordination or work in unusual conditions. However, it is stressed in the literature of the subject that our judgment on automation will change, which according to the majority is a threat only for poorly educated and low-skilled workers. Such an opinion is rooted in the fact that these persons usually perform routine and repetitive tasks. As Ford (2016) observed, the technological boundaries shift extremely fast, and currently the term 'routine work' is not a proper designation of a job endangered by technology – 'predictable work' is more accurate here.

Does the introduction of technological innovation – for example in a warehouse – means that there is a problem of technological unemployment? Matuzeviciute, Butkus and Karaliute (2017) carried out some extensive empirical studies using panel data from 25 European countries between 2000 and 2012. The studies were performed on a macroeconomic level, and the so-called Triadic Patent Family per million inhabitants was taken as a source of information about technological innovation. However, the performed studies did not show any impact of technological innovation on the increase in unemployment. As the authors of those works suggest, the research result may come from certain restrictions in measurements – among others the unemployment rate may be too broad a variable to capture the effects of technological innovations. Moreover, they believe it is hard to estimate the impact of technological innovation on unemployment at the time the innovation is being introduced, because the compensation effects may be delayed, so the research over long-term effects of innovation could be more valid.

Extensive research analyzing the impact of technological innovation on job creation was also carried out by Van Roy, Vértesy and Vivarelli (2018). In their surveys, they took into account a panel data set covering almost 20,000 patent companies from Europe between 2003 and 2012. The obtained results suggested that the positive impact of innovation on employment is statistically significant only in manufacturing sectors of high and medium technological level. It is not relevant in the case of low-tech manufacturing and services.

Will low-skilled workers be replaced because of the introduction of automation of selected processes in an enterprise? To answer that question, Cords and Prettner (2018) developed a job search and matching model for employees, which includes two types of skills (high and low) and the capital of automation as an additional factor of production. Using this type of model, the above-mentioned authors proved that accumulation of the automation capital reduces the labor market tightness for low-skilled workers and increases it when it comes to the high-skilled employees. This leads to an increase in unemployment among people with low qualifications and a decrease in unemployment among those with high qualification. Furthermore, the automation leads to a drop in wages of low-skilled workers and an increase in wages for high-skilled employees.

In turn, Konečný (2016) presented the link between technological unemployment and an enterprise life cycle. In his opinion, enterprises that are in the growth or stabilization phases should replace human work with machines, but they should also prevent leading out the redundant workers to competition – as this would be an indirect form of support for this competition. Replacement of human work with machines is one of the most responsible and risky managerial decisions, so managers should provide it with a high priority. As noted by Konečný, preparation for the replacement of workers with machines should take about ten years.

Introduction of new machines and innovations in work organization are not the only determinants contributing to the necessity to redefine and marginalize human work from the perspective of production and service networks. It is also important to address market issues, knowledge structures, social practices and the interests of companies and corporations that stabilize technological innovation (Afeltowicz, 2007).

2. Research Method

In order to answer the research questions formulated by the authors, the research was conducted on simulation models. These models were developed with discrete events simulation software – FlexSim 3D Simulation Software (version 18.2.2). Models of three warehouses for an enterprise were developed in order to carry out a simulation. For the sake of simplicity, it was assumed that the receipt and dispatch zone is located on one wall of the warehouse, which means that a bag-type warehouse is analyzed. The size and shape of assortment vary. There are 500 storage locations in the storage area for all warehouse models. The assortment is arranged randomly, and in the first model it is stored in shelf racks that allows their retrieval by workers without a need of using any additional devices.

This is an example of a warehouse that may belong to an operator specializing in logistics services for B2C (Business to Customer) or online stores. In this type of warehouses a key piece is a unit. Such a warehouse should be organized in a way that allows quick and easy access to the product. A simulated warehouse is a fulfillment warehouse with full service for receptions and deliveries of goods, as well as packing products in own boxes or packaging provided by the customer.

Orders for all types of warehouses were generated randomly (a source code fragment is presented in Listing 1). The system creates a picking list with a random integer value in the range from 1 to 20.

Listing 1: Source code for order picking in warehouse simulation models

```
/**Custom Code – The algorithm of generating orders for particular goods*/
Object current = ownerobject(c);
Object item = param(1);
int rownumber = param(2); //row number of the schedule/sequence table
for (int i = 1; i <= 20; i++) {
    string a = concat(„B“,numtostring(i));
    item.labels.assert(a).value = 0;
}
int b = duniform(3,6);
for (int j = 1; j <= b; j++) {
    int c = duniform(1,20);
    string d = concat(„B“, numtostring(c));
    item.labels.assert(d).value++;
}
item.Type = 11;
```

Source: own

In the first warehouse presented in Fig. 1, the picking process is performed by 2 workers. Simple picking is used. It means strict order picking, 1:1, namely that an individual picking order is implemented by a single warehouse worker. This model includes a picker to part system – meaning that a worker that performs the picking must reach the storage place of the goods in order to retrieve them.

The second and third model implement technological and organizational innovation consisting in the use of 2 robots (Fig. 2). This warehouse adopts a part to picker system, meaning that a given assortment item is moved to the picking person by means of special robots. Robots of that type used in warehouses (e.g. by Amazon) are quite simple in terms of their construction – they have a pair of wheels and a mechanism for moving shelves/racks with goods. Front and rear sensors for obstacle detection allow two-way transport. They are also equipped with a navigation system intended to search for the codes located on the ground and transport the goods to a correct place.

A change introduced in model second (2 workers and 2 robots) and model third (1 worker

Fig. 1: First warehouse simulation model

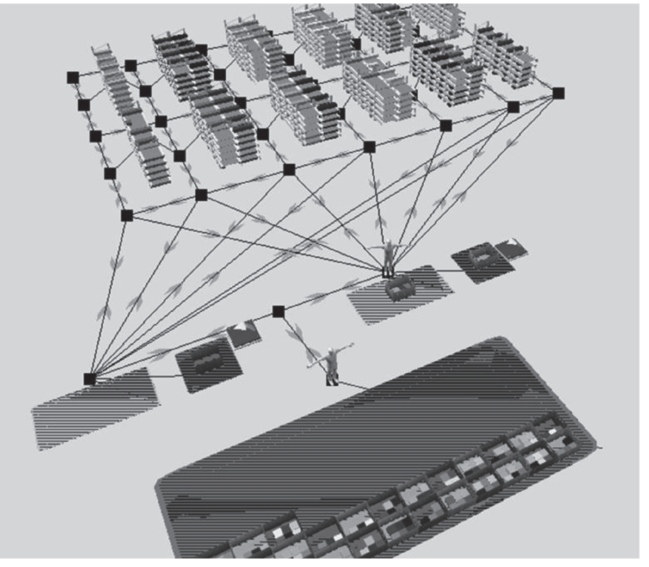

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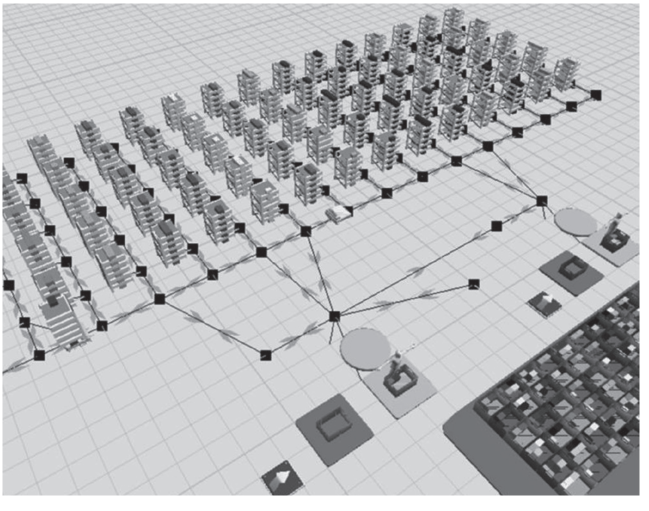
Fig. 2: Second warehouse simulation model



Source: own

and 2 robots) covers four basic steps (Fig. 3) regarding the robot's operations:

1. Go from the current robot location to the current shelf location.
2. Transport the shelf from the current location to the picking station.
3. Stay in line at the station.
4. Retrieve the assortment from the shelf.
5. Transport the shelf back to the location in the storage area.

The mentioned operations are marked with numbers in Fig. 3. Having received the demand for given goods, the robot goes to a particular location. Afterwards, it 'retrieves' the shelf with the demanded goods and transports it to the picking station. When the worker picks up the goods from the shelf, the robot goes back with it to the storage area so it can be put down in a given location. In Fig. 3, the retrieved item is marked as a white square on the shelf. At the picking stations, the workers pack the goods in shipping containers/cardboard boxes and move it to the buffer zone. One robot may transport one shelf at a time, and the shelf can 'visit' one or two picking stations.

The third model also encompasses a unit-load system, which means that a worker does not need to search for and transport unit loads necessary to pick up an order. There are still 2 robots that retrieve the shelves with products and transport them to the picking locations. However, an important aspect of this model is the number of the picking employees. The authors of the paper implemented only one picking station in this model.

The purpose of the simulations performed on models second and third is to obtain data allowing to formulate an answer for a research question considering the impact of robots operating in the picking process on staff workload and the demand for the number of employees.

3. Simulation Results – Discussion

The simulation on individual models was performed for several initial samples, which included a different distribution of the location of goods and a different distribution of the demand for goods. These trials allowed to generate results regarding the station and worker workload in particular models.

This allowed to check which solution improves effectiveness of picking operations. Authors understand the warehouse management effectiveness as results of the operation in given technical and organizational conditions, intended to minimize the resources involved in implementation of tasks within assumed objectives. The measurement of effectiveness was the warehouse productivity presented as a relation of the number of picking orders to the number of devoted man-hours.

The results of the simulation experiment are presented in Fig. 4, which shows the efficiency of picking stations in all models. Four components of a station efficiency were measured: picking process, waiting for necessary materials (collecting and transporting), preparation of a station for work and idle. Their duration is given in relation to the total duration of the

Fig. 3: Robot activity in the second and third warehouse model

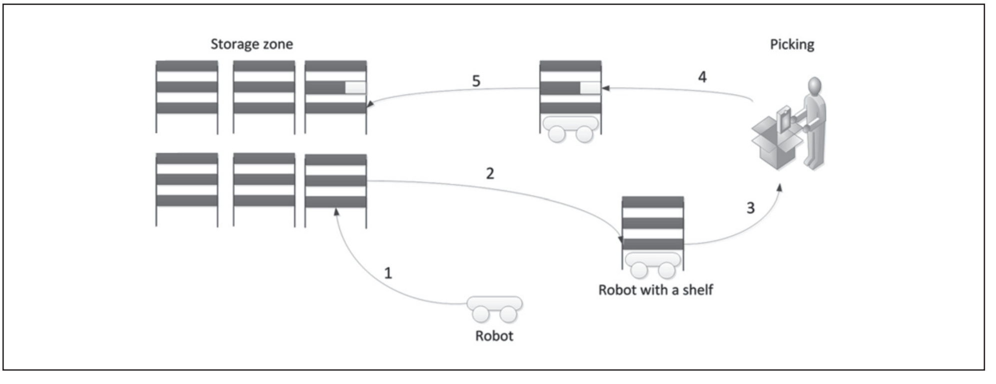


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Fig. 4: **Labor productivity of picking stations in simulation models**

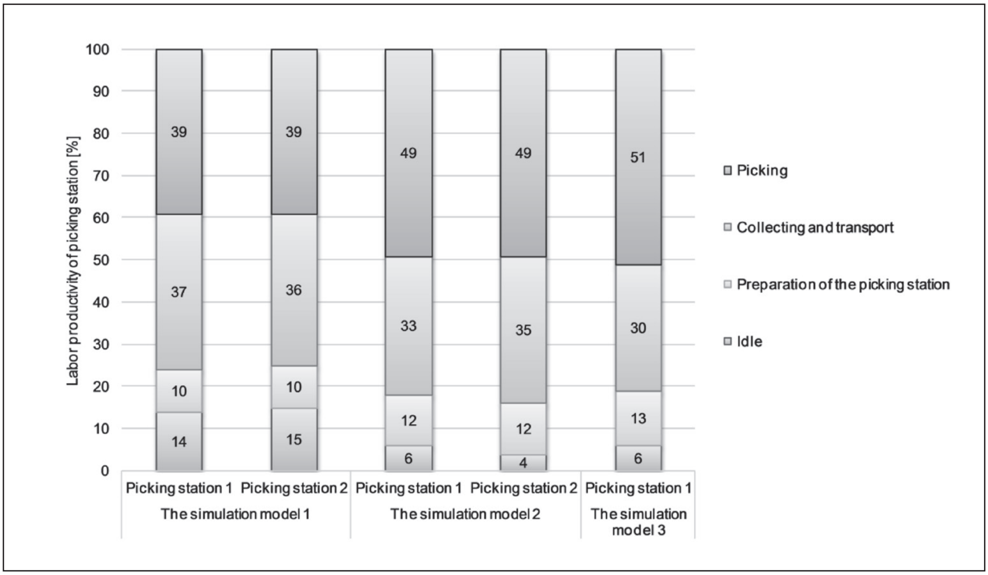

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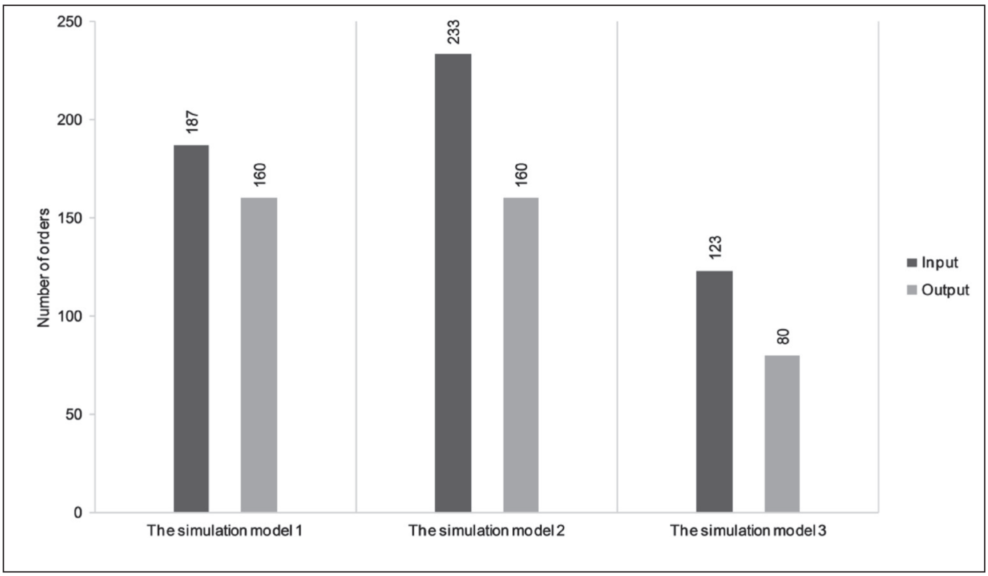
Fig. 5: **Number of orders in simulation models**



Source: own

process. In the FlexSim 3D Simulation Software the allocated idle means that the operator has been acquired by resource but has not been given a task yet.

The obtained results suggest (Fig. 4) that the time devoted to collecting and transporting of goods from the location in the first model is almost equal to the picking time itself, which is 39%. The collecting and transporting time is: 37% on station 1 and 36% on station 2. In the second model (2 robots and 2 picking stations) and in the third model (2 robots and 1 picking station) the collecting/transporting times are similar, while the picking time increases respectively: by 10% in the second model and by 12% in the third model.

Summarizing the results of the simulation, it should be noted that for an enterprise the largest number of completed orders is the second model variant (Fig. 5), in which the picking process takes place with the use of two robots and two picking stations. In the case of models with introduced innovations (second and third simulation models), the picking process in relation to the whole analyzed time was 49–51% (Fig. 4). However, these models experience some idles at the stations:

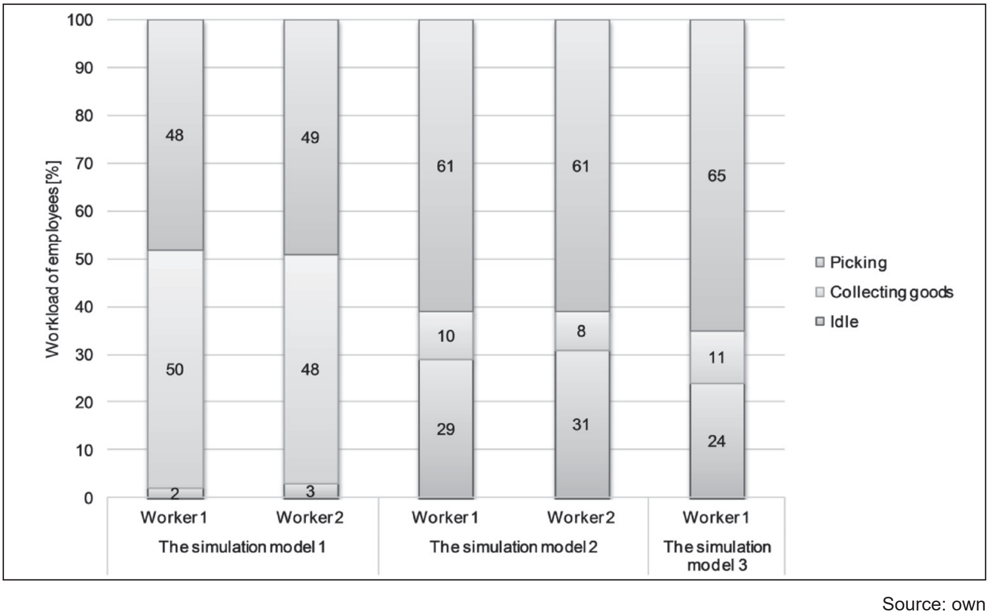
- in the first model it is 14–15% – the idle results from the employees who operate the stations;
- in the second model is 4–6% and in model third: 6% – the idle results from the operator's waiting for the arrival of robot at the picking station with adequate goods.

The simulation tests conducted allow to attempt to answer the first research question formulated in the introduction to this paper: *Will the introduction of a technological and organizational innovation in a warehouse improve the picking process efficiency?*

In the first model, where the workers needed to search for the goods at the picking list and transport them on their own – the number of order was 187 (Input value). The greatest number of orders were handled in the second model (233 orders). The lowest number of orders were handled in the third model (123 orders), where only one picking station operated by one worker was implemented.

Summing up, the technological and organizational innovation introduced into the warehouse improve the picking stations efficiency, and thus the whole picking process.

Fig. 6: Workload of employees in simulation models



Source: own

The number of completed picking operates increased. The productivity grew by 21%, hence proving that the overall warehouse efficiency increased.

Comparing the results with other studies regarding introduction of innovations, e.g. the research conducted by Samattapapong, performance gains have also been achieved once the alterations have been introduced. The result of the simulation (in FlexSim 3D Simulation Software) analysis showed that the conveyor belt was a bottleneck in the warehouse operation. Therefore, many scenarios have been generated to improve this problem and tested in the simulation analysis process. The researcher proposed three solutions (Samattapapong, 2017). These solutions consisted in adding an additional employee in transporting products, adding a transport belt to reduce queues during transport, and adding both an additional employee and a transport belt. The researcher increased the number of shelves. For transport, the researcher applied the FIFO (First In First Out) principle, according to which previously manufactured products will be sent to the customer first. The result showed that the average waiting time in the queue was reduced from 89.8% to 48.7%, and the product's transport capacity increased from 10.2% to 50.9%.

How will the staff workload and demand for workers change after introducing the technological and organizational innovation in the picking process? The answer to the above, namely the second research question is not obvious. The simulations did not allow to examine the mental factor, which was separated in the studies by Grosse, Glock and Neumann (2015). This factor, even in real conditions, is difficult for direct and quantitative estimation. However, we can put forward a working hypothesis that introduction of innovations by adopting robots for transport of goods in warehouse second and third contributed to improvement of this factor. A worker no longer needs to carry out the work related to searching for and transporting good, which relieves his psyche from additional activities and allows to focus strictly on the activities related to picking (goods control, control of the picking list with delivered goods, securing containers, etc).

Moreover, by analyzing the models and the obtained data it is possible to draw conclusions related to the physical factor of a worker, which will be determined mainly by work related to the transport of goods. In model first (Fig. 6), where no innovation has been introduced, a worker fatigue will result not only from work at the picking station, but also from searching, manipulating and transporting goods from the storage area to the workstation. The time devoted to collect the goods, which is 48–50%, is comparable with the time devoted to operating the picking process, which is 48–49%. These results prove great physical strain, as it is about 98% in both cases of workers. There is not much possible impact to be exerted on the station during the picking process. While the time related to transport can be extensively influenced. Therefore, the innovation was introduced in subsequent models. After adopting the robots to transport in models second and third, the picking time increased to 61–65%, while the collecting time was reduced to 8–11% – which generally indicates lower workload for the worker. Picking employees are most often exposed to countless injuries caused during reaching, lifting, picking and moving packages, moving between picking places. The introduction of technological innovation in this process in this case increases the safety of order pickers. It is true that the idle time increase, and it is 24–31% of the total time – unlike the value from the first model, which was 2–3%. But the time in the second and third models results from the workers waiting for the robot to arrive. Furthermore, this is when a worker can fill in the documentation, clean the workstation, etc, namely do those actions that were omitted in the simulation, but which are a part of the daily duties of each picking worker.

Therefore, while answering the question related to the workload, we can conclude that the innovation reduced the staff workload on the picking station in physical terms.

The conducted simulation test did not show any significant impact of introducing robots into the picking process on the number of workers needed for its implementation. Efficiency of picking activities at the picking station in model third (with 1 worker) is the highest (51%), but still comparable to model second (with 2 workers) – where it is 49%. Also the efficiency values related to picking/transporting the goods, preparing the station for work and with idle time are also comparable. Decrease of the number of workers from 2 to 1 proportionally reduces the number of completed orders (Output – from 160 to 80). However, it should be stated that introduction of other innovations in the warehouse, in particular of technological nature (forcing technological changes) becomes a natural and often simply necessary matter. Especially if we take into account the important role that warehouses are to play in the implementation of the concept of Industry 4.0. The number of employees employed 24 hours a day is reduced by introducing solutions that increasingly automate warehouse processes. It is also worth noting that the decision on the degree of automation is connected with a preliminary analysis of labor costs and the local market for which a given warehouse system installation will be designed. A challenge in automation still includes large variety of packaging, integration of autonomous vehicles or reliable IT warehouse system.

The simulation tests performed do not take into account financial and economic factors nor the ones related to human resources in the context of personnel policy or sociology of work connected with introduction of robots to the picking process. Decisions concerning buying robots or renting them in the 'robots-as-a-service' (RaaS) model are still associated with high costs. It should also be emphasized that in the broader economic perspective the role of the warehouse operating within the modern supply chain is shaped by the features of volatility (e.g. fluctuations in consumer markets) and risk management (e.g. changes resulting from new legal regulations, the use of outsourcing services – third-party logistics or temporary employment of additional employees). In addition, the decision to introduce technological innovations in the picking process is not always the result of the expected improvement in efficiency, cost reduction and quality and safety at work. It also results from relationships with suppliers, markets in which the company competes. The problem of handling the increasing number of orders directed to warehouses, with relatively low employee wages, is often solved by temporary employment of additional workers. Thus, the decision to make expensive – and potentially risky – investments in technologies that change quickly is postponed. The result of picking processes automation is also the appearance of restrictions in the interaction of employees with colleagues. The possibilities of helping each other in performing tasks or solving problems are eliminated. The introduction of automation is accompanied by new forms of employee control, detailed tracking of their movements, routes, speeds, breaks. Consequently, systems can encourage individual employees to be more productive. This can lead to deterioration of working conditions and negatively affect employee morale (Gutelius & Theodore, 2019).

Conclusions

In today's highly dynamic business environment, enterprises need to develop innovative strategies and tools to keep up with the technological changes and adapt to conditions of global competition. High variability of business surroundings triggers the need to introduce innovations in the area of production and warehouse processes. Important factors that determine application of new technologies and introduction of innovation include the tendency to reduce the time of product design, production and order picking so it can be delivered to the customer. A warehouse is becoming an increasingly critical link in operations of enterprises. The above-mentioned factors force enterprises to reduce inventory, shorten lead times and decrease operating costs. As a result, new and automated picking processes can significantly increase the efficiency of this process, but on the other hand they may result in organizational changes.

The results of tests presented in this study allow to formulate a positive general evaluation of the effects of introducing technological and organizational innovation in the warehousing process. A basic effect is an increase in 'productivity' of the warehouse operation understood as a relation of the number of picking orders to the number of devoted man-hours and an increase in efficiency of the picking process. Staff workload is reduced – in both the physical and mental dimensions. This may be reflected in greater comfort of work for a man and support implementation of control activities. However, it is difficult not to notice the potential problems with maintaining the previous employment levels due to the worker market and in a longer time horizon. Automation and digitalization processes taking place in enterprises change the labor market. This is not synonymous with the situation that human work becomes less necessary. New professions emerge, and effective introduction of innovation and the use of new technologies and new work organization models will require knowledge, quick decision making, and first of all creativity, flexibility and the willingness to introduce changes.

The results of the research presented in the article indicate the need for further simulation experiments in the scope of the topics presented in the article. It would be interesting to provide the warehouse simulation models with other picking stations (for example in a configuration of two robots and three picking stations). A larger number of workers in the model would allow fuller response to the question on the impact of technological and organizational innovation on the number of employed workers. In addition, the literature analysis also revealed a research gap related to the impact of introduction of technological and organizational innovation on human work from the worker's perspective. Therefore, future research conducted by the authors will be focused on examining the innovation impact on the worker workload in real conditions in physical and mental terms.

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