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Organization of the internal transport process in the warehouse

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***Abstract*— Background: Internal transport in the warehouse is a key element of this process. Its effectiveness will determine the time it takes to complete individual tasks. In times of growing competition, it is difficult to compete with the price of services. Nowadays, a customer is willing to pay more if he receives the ordered goods on time or even before the deadline. Improving the functioning of transport in the warehouse is a current topic. Due to increasing automation and the expanding possibilities of using newer equipment, many companies are analyzing such possibilities. However, this is not necessary everywhere, sometimes the element that needs to be introduced is the reorganization of the existing technological system of the warehouse in such a way as to increase its efficiency.This article uses a computer simulation method using the FlexSim program and the indicator method to evaluate the proposed solutions. To apply the indicated methods, real data obtained from the company, own observations and interviews with company employees were used. Three new warehouse space models developed for the reorganization show that there is a need to change the current warehouse layout. Working in the current arrangement is ineffective and dangerous due to the company's profile. The obtained results of indicator calculations clearly show that the new warehouse model will be a better solution for the examined company. Based on the research conducted, it is recommended for the examined company to change the organization of the warehouse to a new model, the use of which will not only shorten the internal transport time but will also significantly increase the work safety of employees. The new warehouse model, described in detail, will bring many benefits to the company. Further research may concern a new model or a change in means of transport in the warehouse. An additional facilitation may be the use of 19 steps as a method supporting the organization of internal transport and designing the warehouse layout.**

Keywords— transport, security, computer simulation, warehouse

I. INTRODUCTION

Adapting the operation of internal transport to the warehouse facility and the technical infrastructure located in it consists of a complex series of activities, where the optimization of warehouse processes is sought based on many variables [Dybała 2020]. Improving the functioning of transport processes in a warehouse is possible only on the basis of the results of an in-depth analysis of the warehouse processes taking place in it and the characteristics of the goods handled in it, so as to fully use the possibilities of other processes taking place in the enterprise and, consequently, contribute to its development and increasing the level of competitiveness on the market [Galińska 2016], [Pyza, Jachimowski, Jacyna-Gołda, Lewczuk 2017]. To fully understand the essence and importance of internal transport, we must first refer to transport as a whole - in logistics it is an extremely important element that is the subject of continuous analysis, as it is estimated that it constitutes up to 75% of the overall costs in the logistics cost structure [Gołębska 2016].

The surveyed company has a recently purchased warehouse which, in order to fully utilize its potential and be able to fulfill all orders safely and quickly, must design its space in such a way that internal transport can perform its tasks in the shortest possible time. Currently, this warehouse is functioning properly, but certainly not efficiently. Appropriate improvements must be made. Therefore, the aim of this work is to develop a warehouse model that improves transport and increases employee work safety. This model should meet the conditions set by the company and meet the market needs of target customers [Głodowska, Świderski 2019].

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II. Materials and methods

The XYZ company has been operating in the production and service industry on the Polish and foreign markets for 25 years. The main core of the company's operation is the design, manufacture, assembly and servicing of machines and assembly lines intended for the automation of production lines. The company's main clients include enterprises from the industrial sector producing car parts and components, household appliances and electrical engineering. An important element of the examined enterprise is a warehouse with the working name MAG. This is where materials and semi-finished products necessary to produce machines and devices ordered by external customers are stored, and it is the weak link. Mainly structural profiles of irregular dimensions are stored there, which significantly complicates the storage process. The profiles are placed on cantilever racks included in the warehouse equipment in the free storage system. Racks used for storing profiles in the warehouse have the following dimensions (for one-sided storage): 50×12×20 m, for storing goods using brackets on both sides: 50×25×20 m. The use of cantilever racks brings the benefits of the possibility of modulating the shelf structure and adapting it to the current needs related to the number of storage spaces. The warehouse currently has five such racks. Additionally, the facility has modular shelf racks divided into two modules, each with dimensions of 100×15×25 m, which are used for storing waste after profile cutting and as a storage area for tools needed by the saw operator. Construction profiles have two purposes. The first is to use them internally in the company's production processes to make structures from them according to customer specifications. The second purpose of the profiles is their sale based on orders received from outside. In both cases, the relevant profiles undergo basic processing before being released, which happens in the warehouse area MAG. This facility is the property of the company. The building is a closed warehouse with internal dimensions of 503.2 × 234.1 m. It has 3 unloading gates, of which only two are in use - the widest one is 5.6 m wide, the smaller one is 4.5 m wide. A characteristic feature of the building is the fact that there are columns supporting the structure of the facility along its entire width. These columns are spaced every 5.7 m. Additionally, the length of the building is divided into two zones; the zone on the right is intended only for handling orders regarding construction profiles, hence internal transport in this zone will be the main subject of considerations.

Before starting work on improving the functionality and reorganization of the warehouse space, all input data should be carefully determined to enable the most accurate illustration of the current situation and identification of weak links. The primary goal for improving the MAG warehouse is to shorten the duration of transport tasks performed in the company and to increase the safety of employees at work, especially when handling long goods. Therefore, 19 steps were developed when identifying the current state (step 1-10) and proposals for improvements (step 11-19). The most important tool used to conduct the research was the FlexSim simulation program. It is used to map and optimize processes. Process simulation involves the virtual introduction of elements of a real system to analyze it and find improvements. This allows you to examine the issue of equipment and staff load, efficiency, productivity, transport, and internal logistics. Properly programmed experiments make it possible to determine optimal and cost-effective solutions from among tens of thousands of possibilities. Using the FlexSim program, you can obtain information, e.g., how much time the production process takes in each production line configuration. You can also build any infrastructure, selecting the smallest details, along with 3D visualization [Jacyna, Bobińska, Lewczuk 2017].

III. Practical example

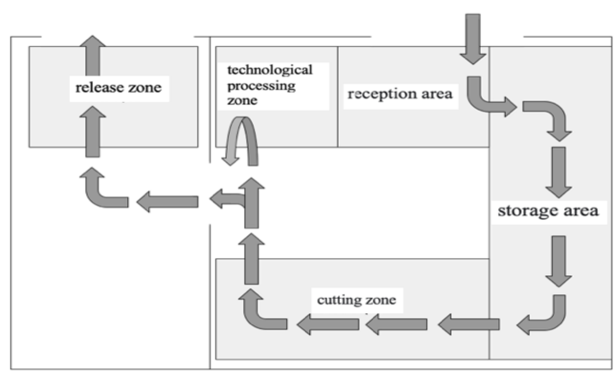
Many computer simulations organizing the space of the MAG warehouse were developed for the examined company. It is impossible to describe all of them in this article, so the solution that was implemented in the company using 19 steps will be presented.:

Step 1. Start of the process.

Step 2. Isolation of important features of the examined object.

The tested facility is a closed facility intended for storing long goods on low-storage racks. The current technological layout of the warehouse is a bag system with separated reception and release zones. The facility includes a reception zone, a storage zone, a release zone and two additional zones: a cutting zone and a technological processing zone. Machining and cutting processes take place in the warehouse every day except delivery days. The technological layout of the warehouse facility with the marked material flow is shown in Figure 1, and the most important design features are listed in Table 1.

FIG. 1 TECHNOLOGICAL LAYOUT OF THE MAG WAREHOUSE



Source: own study

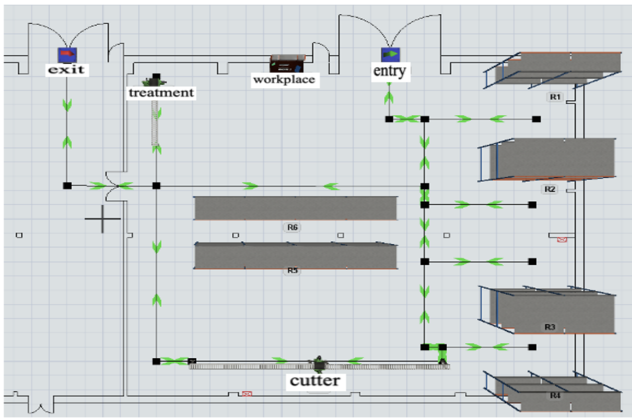
TABLE 1 DESIGN FEATURES OF THE MAG WAREHOUSE

The examined feature of the object	the size of the feature	unit
Dimensions of the warehouse facility	25500×23410	mm
Maximum storage height	3000	mm
Gate width – entrance	5600	mm
Gate width – exit	4500	mm
The width of the passage between zones	1900	mm
Column spacing	5700	mm

Source: own study

Computer workstations have been placed in the receiving area of the MAG warehouse, enabling employees to quickly receive goods during deliveries. It is worth noting that the receiving area is only used to receive construction profiles - all other deliveries are received on the other side of the warehouse where the issue area for profiles is indicated. The technological layout of the warehouse was mapped in the FlexSim program and presented in drawing number 2.

FIG. 2 MODEL OF THE CURRENT STATE OF INTERNAL TRANSPORT ORGANIZATION IN THE MAG WAREHOUSE



Shelves: R1-R4 are cantilevers intended for storing albumin profiles, R2-R3 have brackets on both sides of the supporting structure, R5-R6 are intended for cutting waste. Figure 2 shows a device called "saw", it is a station for cutting profiles, with roller feeders placed at it, so that the operator can perform his work safely, the minimum space he needs is specified - the dimensions of this space are 16 × 5 m. Icon called "processing" is a station for technical processing of metal profiles in accordance with the order specifications. The space it occupies is 6.5 x 5 m.

Step 3. Determining the requirements for the functioning of the transport process.

The examined company currently has a problem resulting from the unfortunate spacing of the warehouse's supporting structure. Transport processes performed in the MAG warehouse are very long due to the need to rotate profiles so as not to damage the goods or the building. Maneuvering profiles and long transport routes are also a great effort for employees who operate the warehouse manually. Hence, the main requirements for the functioning of internal transport are short transport routes, minimization of the need to rotate profiles and a high level of comfort and safety of employees.

Step 4. Determining the activities related to handling the goods.

The nature of the transformation of goods handled in the facility falls within the scope of warehouse tasks - profiles are subject to the operations of movement, storage, retrieval, and issue. Additionally, they are cut and technically processed in the warehouse, which takes place every day except for the days when the profiles are due for delivery. Goods are stored in a system of free storage spaces, but care is taken to place heavy profiles lower. The decision as to where to store the goods is made by the employees receiving the goods. The distribution takes place within the LIFO system – last in, first out.

Step 5. Determining transport tasks.

There are 5 main transport processes in the MAG warehouse:

1) transport from the issuing zone to the storage zone (racks R1-R4),
2) transport from the storage zone to the cutting zone,
3) transport from the cutting zone to the technological processing zone,
4) transport from the technological processing zone to the release zone,
5) transport from the cutting zone to the release zone.

The execution times of these transport processes will be the basis for analyzing the functioning of the MAG warehouse transport system.

Step 6 and 7. Identification of the start and end points of the displacements.

The starting points of the movements are: entrance, racks R1-R4, cutting station, processing station.The end points of the movements are: racks R1-R4, cutting station, processing station, exit.

Step 8. Determining the displacement distance.

TABLE 2 DISTANCES OF DISPLACEMENTS OF THE INITIAL MODEL IN THE MAG WAREHOUSE

Starting point	End point	Distance of movements [m]
Entry	R1	10
	R2	16
	R3	20
	R4	26
R1	Cutting station	23
R2		17
R3		13
R4		5
Cutting station	Processing station	17
Processing station	Exit	16
Cutting station	Exit	27

Source: own study

Step 9. Determining the conditions of displacement

Pillars supporting the building's supporting structure are located along the warehouse component. For this reason, during transport processes, it is necessary to rotate the profiles many times by 90° to fit into narrow passages. An additional difficulty are two hydrants located in the storage space. To ensure the safe operation of the warehouse, it is necessary to secure these spaces and allow free access to them.

Step 10. Determining the duration of the movements.

For the process of determining the duration of movements, assumptions were made regarding the performance of activities in the warehouse by employees (Table 3), and the duration of movements between racks were recorded in Table 4. For the calculations, the assumptions were made that employees move around the warehouse at a speed of 2 km/ h regardless of the weight of the load they are carrying at a given moment.

Tabela 1 Czasy wykonywania czynności związanych z przemieszczaniem ładunków

Table 3. Times for carrying out activities related to the movement of loads

TABLE 3. TIMES FOR CARRYING OUT ACTIVITIES RELATED TO THE MOVEMENT OF LOADS

Action	Execution time [s]
Downloading the profile from the input	5
Assembling the profile on the shelf (at hip height)	15
Taking a profile from the shelf (at hip height)	10

Action	Execution time [s]
Rotating the profile by 90°	15
Position of the profile on the cutting station	20
Downloading the profile from the cutting station	10
Location of the profile on the processing station	5
Downloading the profile at the processing station	5
Postponing the profile at the output	5

Source: own study

TABLE 4. MOVEMENT TIMES BETWEEN RACKS IN THE MAG BASELINE MODEL

Rack	transport from the entrance to the shelf			transport from shelf to cutting		
	Distance [m]	Transport time [s]	Number of revolutions	Distance [m]	Transport time [s]	Number of revolutions
R1	10	40	1	23	71,5	2
R2	16	43	1	17	68,5	2
R3	20	45	1	13	66,5	2
R4	26	48	1	5	32,5	0

Source: own study

The duration of movements between the racks and the entrance and between the rack's ranges from 80.5 to 115.5 s. It can be noticed that the R4 rack is characterized by the shortest total transport time; this is since during the transport of the shelf - cutting station there was no need to rotate the profile. The duration of the movements between the workstations and the exit are presented in table 5. Profiles that have already been cut in accordance with the orders are no longer subject to rotation by 90°.

TABLE 5. MOVEMENT TIMES BETWEEN WORKSTATIONS AND THE EXIT IN THE MAG MODEL

Starting point	End point	Distance [m]	Transport time [s]
Cutting station	Processing station	17	23,5
Processing station	Exit	16	18
Cutting station	Entry	27	25,5

Source: own study

The duration of movements on the routes between the workstations and the exit range from 18 to 28.5 s, with the longest transport time being on the cutting-exit route - 28.5 s. Since there is no need to perform additional manipulations of the construction profiles on these routes, durations are dictated entirely by displacement distances. It is important to indicate the transport time on the cutting-processing-output route, which is 41.5 - this time is higher than the cutting-output transport time, which may suggest that the technological processing station is located too far from other stations, hence generating redundant process duration. To standardize the comparison of models of warehouse technological systems, it was assumed that the transport time of profiles to the cutting zone is equal to the average duration of displacements between racks R1-R4 and the cutting zone in the tested model. Waiting times for the completion of cutting and machining processes are not included. The duration of the transport process is presented in formula 1.

$$T_{trans} = \bar{t}_{RC} + t_{CO} + t_{OW} \quad (1)$$

Where: $\bar{t}_{RC}$ – average transport time from the rack to the cutting zone; t_{CO} – transport time from the cutting zone to the processing zone; t_{OW} – transport time from the processing zone to the exit.

The same situation occurs in the delivery process; it was assumed that the transport time of the profiles to the rack is equal to the average duration of movements between racks R1-R4 and the entrance. The duration of the process of placing the profile on the shelf is shown in formula 2.

$$T_{dost} = \bar{t}_{WR} + \bar{t}_{RW} \quad (2)$$

Where: $\bar{t}_{WR}$ – average transport time from entry to shelf; $\bar{t}_{RW}$ – average return time from the shelf to the entrance.

According to formula 1, the process duration for the MAG warehouse input model is:

$$T_{trans} = \frac{71{,}5 + 68{,}5 + 66{,}5 + 32{,}5}{4} + 23{,}5 + 18 = 101{,}25 \approx 102\ s$$

According to formula 2, the process duration for the MAG warehouse input model is:

$$T_{dost} = \frac{40 + 43 + 45 + 48}{4} + \frac{5 + 8 + 10 + 13}{4} = 53\ s$$

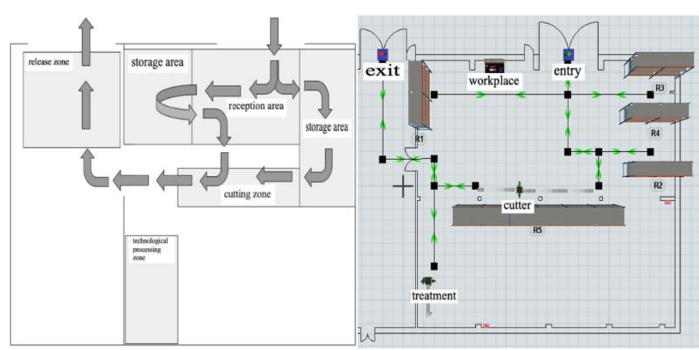
Results

The next step, after completing the first 10 steps, i.e. the part common to all models developed for the purposes of this work, is to step 11, which begins research on the developed simulation models. Three models were developed for the tested facility, from which the best solution (MAG3) was selected and will be discussed in detail. It would be impossible to describe all simulations, so the focus was on the solution used in the examined company.

Step 11. Modeling the technological layout of the warehouse.

The MAG3 model is based on minimizing the transitions between the pillars supporting the supporting structure, as well as reducing the distances between the racks and the cutting zone and the cutting zone and the processing zone. The model assumes that technical equipment will be maintained on only one side of the warehouse, with the exception that these devices are located at the front of the warehouse (Fig. 3).

FIG. 3 TECHNOLOGICAL LAYOUT OF THE MAG3 MODEL (LEFT SIDE), MAG3 WAREHOUSE MODEL (RIGHT SIDE)



Source: own study

Similarly, to the original warehouse layout (MAG), R1-R4 cantilever racks were used for storage, however, in order to be able to move them under the warehouse walls, it was necessary to resign from storing profiles on both sides of the structure in R2-R3 racks - this reduced the maximum number of storage places. The R5-R6 racks used in the MAG model were moved to the part of the warehouse behind the pillars supporting the warehouse's supporting structure. In the MAG3 model, it was decided to move the “cutter” cutting zone to the center of the facility in front of the pillars - this way the distance between the station and the racks was reduced. The technological machining zone is in the same place as in the MAG model.

Step 12 and 13. Identification of the starting and ending points of the model displacements.

The same displacement points were determined as in all tested models and the original MAG model.

Step 14. Determining the model displacement conditions.

In the proposed model, internal transport routes are shorter than in other models, and the need to rotate profiles when picking them from R2-R4 racks is removed.

Step 15. Selection of transport technologies for the tested model.

Due to the structure of the facility and the nature of the stored materials, manual technology was chosen.

Step 16. Determining the model displacement distance.

Table 6 lists the distances of movements in the warehouse.

TABLE 6 DISPLACEMENT DISTANCE OF THE MAG3 MODEL

Starting point	End point	Distance of movements [m
Entry	R1	15
	R2	15
	R3	15
	R4	10
R1	Cutting station	22
R2		7
R3		17
R4		17
Cutting station	Processing station	10
Processing station	Exit	23
Cutting station	Exit	19

Source: own study

Step 17. Determining the duration of model displacements.

Table 7 lists the times of movements between the racks and other zones.

TABLE 7. MOVEMENT TIMES BETWEEN RACKS IN THE MAG 3 MODEL

Rack	transport from the entrance to the shelf			transport from shelf to cutting		
	Distance [m]	Transport time [s]	Number of revolutions	Distance[m]	Transport time [s]	Number of revolutions
R 1	15	27,5	0	22	56	1
R 2	15	42,5	1	7	33,5	0
R 3	15	42,5	1	17	38,5	0
R 4	10	40	1	17	38,5	0

Source: own study

The duration of the movements between the workstations and the exit are presented in Table 8. Profiles that have already been cut in accordance with the orders are no longer subject to rotation by 90°.

TABLE 8. MOVEMENT TIMES BETWEEN WORKSTATIONS IN THE MAG3 MODEL

Starting point	End point	Distance[m	Transport time [s]
Cutting station	Processing station	15	22,5
Processing station	Exit	25	22,5
Cutting station	Exit	16	23

Source: own study

The duration of the movements on the routes between the workstations ranges from 20 to 24.5 s. To facilitate the process of assessing the MAG3 model and the possibility of comparing it with the input model, calculations were made of the size T_trans and T_dost:

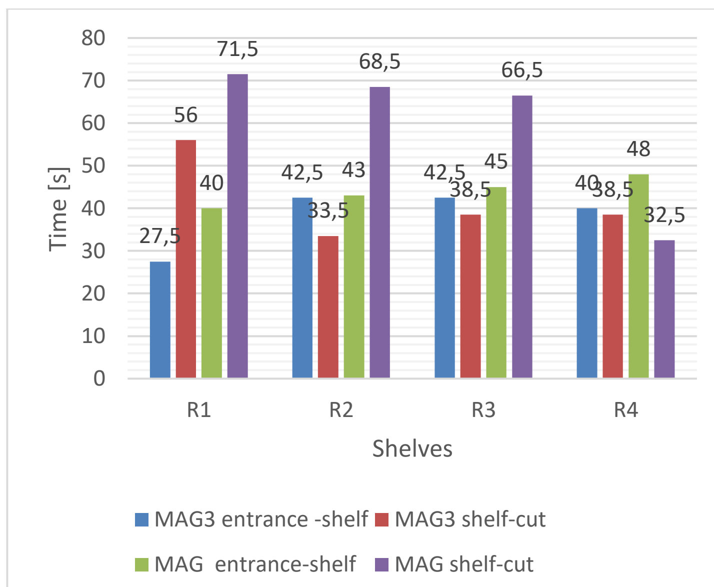
$$T_{trans} = \frac{56 + 33{,}5 + 38{,}5 + 38{,}5}{4} + 21{,}5 + 24{,}5 = 83{,}125 \approx 84\ [s]$$

$$T_{dost} = \frac{27{,}5 + 42{,}5 + 42{,}5 + 40}{4} + \frac{7{,}5 + 7{,}5 + 7{,}5 + 5}{4} = 45\ [s]$$

Step 18. Verification of the adopted model.

The MAG3 model can be implemented in a specific warehouse space. The durations of displacements between racks R1-R4 in this model compared to the original MAG model are shown in Fig. 4.

FIG. 4 COMPARISON OF MOVEMENT TIMES BETWEEN MAG-MAG3 RACKS



Source: own study

The comparison of T_dost and T_trans for MAG and MAG3 models are presented in Table 9.

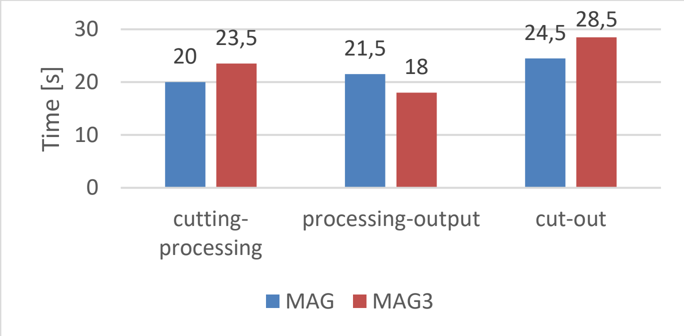
TABLE 9 COMPARISON OF THE DURATION OF THE T_DOST AND T_TRANS PROCESSES FOR THE MAG AND MAG3 MODELS

Model	T_{dost} [s]	T_{trans} [s]
MAG	53	102
MAG3	45	83

Source: own study

A comparison of the displacement durations is shown in Figure 5.

FIG. 5 MOVEMENT TIMES BETWEEN WORKSTATIONS IN THE MAG AND MAG3 MODELS



Source: author's own study

IV. Discussion

In the MAG3 model, it was proposed to divide the storage zone into two parts in order to fully use the space in the front part of the warehouse facility. Placing technological devices in one half of the warehouse allowed for minimizing transport routes in the tested model. The need to transport goods behind the pillars supporting the supporting structure was also eliminated. Analyzing the processes occurring during deliveries, the process of transporting the delivery to the rack from the entrance in the warehouse facility is shorter in the case of the MAG3 model than in the case of MAG, regardless of the rack being tested. For transport processes from racks to the cutting zone, the MAG3 model shows lower travel times in racks R1-R3 compared to the original model; the exception is the R3 rack, in which the transport time is 6 seconds more compared to the original MAG model. The duration of movements between the racks and the entrance and between the racks ranges from 76 to 83.5 s. It can be noticed that the service and movement times related to the racks remain at a very similar level, with a maximum difference of 7.5 s. Additionally, the model MAG3 is characterized by lower execution times of sample transport tasksT_{dost} and T_{trans} than the original MAG model. Comparing the duration of the example transport task, it can be seen that the MAG3 model achieves much better results than the original model. The example transport task performed in the tested model is 19 seconds faster than in the case of the current system used by the company. The times of the transfer processes between the workstations and the exit are at a similar level for both MAG and MAG3 models. The MAG3 model has shorter travel time between cutting station and cutting station and output, and the MAG model has shorter travel time between machining and output. The average relocation time is lower for the MAG3 model and amounts to 22 s. Summarizing all the information, it can be certainly stated that the MAG3 warehouse model meets the assumptions and requirements set by the company, at the same time demonstrating shorter relocation times, shorter transport routes and fewer places where complex manipulation of profiles is necessary while ensuring work safety.

V. Conclusions

For a warehouse to function properly in logistics chains, it must have an effective internal transport system. Creating such a system from scratch or improving the currently used system involves a complex series of decisions and actions that can lead to the optimization of warehouse processes and, consequently, have a positive impact on the operations of the entire company. For this reason, there is a constant need to improve, improve and search for new solutions in the field of internal transport in enterprises in order to maximize the effects and minimize the costs resulting from these processes.

VI. Bibliography

Dybała A., "Optimization of logistic warehouse processes based on the XYZ company", in: Fajczak-Kowalska A. (ed.), Technologies and new trends in management and the development of enterprises in the TSL sector, Wydawnictwo Politechniki Łódzkiej, Łódź 2020.

FlexSim. Avilable from https://flexsim.pl/flexsim/

FlexSim. Avilable from https://flexsim.pl/symulation-procesow-z-flexsim/

Galińska B., Warehouse management, Difin, Warsaw 2016.

Gołębska E., Compendium of knowledge about logistics, PWN, Warsaw 2010, p. 107.

Głodowska K., Świderski A., The importance of the selection of transport technology when applied to the optimization of the internal transport process in the picking zone, Gospodarka Materialowa i Logistyka, Warszawa 2019, no. 5.

Jacyna M., Bobińska A., Lewczuk K., 3D modeling and simulation of warehouse facilities, PWN, Warsaw 2017.

Logistics for logic. Aviable from https://logistykanalogike.wordpress.com/2017/03/24/do-czem-sluzy-flexsim/

Pyza D., Jachimowski R., Jacyna-Gołda I., Lewczuk K., Performance of Equipment and Means of Internal Transport and Efficiency of Implementation of Warehouse Processes, 10th International Scientific Conference Transbaltica 2017: Transportation Science and Technology, Vilnius 2017.