SELECTION OF INTERNAL TRANSPORT TECHNOLOGY WITH THE USE OF SELECTED TOOLS

Katarzyna Głodowska, Małgorzata Grzelak, Tomasz R. Waśniewski

Abstract

The article was devoted to the use of selected tools to decide on the choice of internal transport technology. Technology is understood as the degree of mechanization of internal transport means. For this purpose, the characteristics of internal transport and technology were discussed, and then the factors and criteria that should be considered when choosing internal transport technology were presented. On this basis, an algorithm for the selection of internal transport technology was presented and discussed, and simulation studies were carried out using the FlexSim program. The aim of the article was to analyze and evaluate the possibility of using simulation software to support decision-making regarding the selection of internal transport technologies in a warehouse. The following working hypothesis was adopted – the use of simulation software supports the decision-making process by indicating the most effective solution for implementing transport technology in the warehouse. The research problem was: Is it possible to support the decision-making process regarding the selection of transport technology using simulation software? The last step describes the results of the computer simulation and presents the conclusions. The developed algorithm and its practical implementation can be used by warehouse designers to cost-free check their solutions and selected storage and transport technologies.

Keywords:

transport, technology, computer simulation, safety

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Introduction

Internal transport is an extremely important element of the logistics chain. Used on a large scale in warehouse and production companies. It is characterized by high frequency over short distances. It has been developed very intensively in recent years. It is a key element of many enterprises, so if poorly organized and not improved, it may constitute a weak link. Therefore, it is very important that the transport is appropriately matched to the needs and capabilities of the examined enterprise, which also means choosing the right internal transport technology. Making the right choice should be preceded by a broad and thorough analysis. To carry it out, it is worth using dedicated tools available on the market. Such a tool may be the use of existing algorithms, i.e. sequences of procedures. The use of the algorithm brings many benefits, including the need to determine criteria and factors for the examined enterprise in terms of economic, organizational, capabilities and needs. After determining all the steps needed to apply the algorithm, the resulting result and image can be precisely modeled in a computer program. Then conduct research and obtain results that need to be analyzed. Such a procedure significantly facilitates making the right choice, minimizes the risk of making a wrong choice and significantly reduces costs, because simulation modeling does not require large financial outlays. However, it is crucial to familiarize yourself with the technologies available on the market and the possibilities of their application. The aim of the article was to analyze and evaluate the possibility of using simulation software to support decision-making regarding the selection of internal transport technologies in a warehouse. The following working hypothesis was adopted – the use of simulation software supports the decision-making process by indicating the most effective solution for implementing transport technology in the warehouse. However, the research problem was formulated as a question: Is it possible to support the decision-making process regarding the selection of transport technology using simulation software?

The article consists of three main parts. The first one presents the theoretical basis of internal transport and characterizes the technology. The second chapter was devoted to presenting internal transport technology. In the third, empirical part of the work, the effectiveness of the implemented internal transport technology was implemented and analyzed based on the developed simulation model.

1. Theoretical approach to internal transport and technology

Transport (Latin: transportare – to carry, to transport), as a common element of the economy and social life, involves the paid movement of people or loads in space, from the point of shipment to the point of receipt, using appropriate means of transport [7], [24]. It is therefore a production process whose main task is to overcome space [19]. The following branches of transport are distinguished: land, water, air and special. Transport is divided into internal and external. Transport is an activity that involves the paid (or unpaid) provision of services that result in the movement of cargo and/or loads from the point of origin to the point of receipt, as well as the provision of auxiliary services directly related to these services [1]. Internal transport refers to all activities used to transport people and goods using appropriate means of transport within one enterprise. It is also referred to as intra-plant or close transport [9], [23]. Internal transport can also be divided according to the tasks performed:
- storage and warehousing transport, which includes the receipt and shipment of materials; both their storage in warehouses and warehouses of the company;
- production transport, related to the product production and handling process;
- interdepartmental transport as an element of production transport, runs between production departments;
- intra-departmental transport, which is an element of production transport, but takes place inside individual production halls;
- inter-station transport, which is included in production transport, takes place between workstations;
- stationary transport as an element of production transport, takes place at a specific station.

The key tasks of internal transport include, among others: movement of goods within a given warehouse. Depending on the type of business and its size, there are many organizational models. A characteristic feature of internal transport is that it can be carried out using various means of transport, even those used in external transport. Internal transport also includes transport within enterprises from the receipt of materials to the shipment of finished products. Therefore, internal transport requires:
- optimal transport speed while maintaining the safety and quality of the transported goods;
- loading and unloading times as short as possible;
- short transport routes (while maintaining appropriate distances and safety conditions);
- using appropriate means of transport;
- elimination of reloading or small amounts of reloading;
- the use of transport technology appropriately matched to the needs and possibilities;
- transported load units as unified as possible.

It should be noted that internal transport is divided into closely related transport with the production process and internal transport, not related to this process, carried out in warehouses. For internal transport to function properly, it must be properly organized and selected to suit the organization of the company. There are many methods of selecting transport, and one of them includes selecting the appropriate technology. Technology is defined as a science dealing with general and specific regularities accompanying processes. In his research and generalizations, he largely uses the methods and principles of praxeology, i.e. the general theory of efficient human action [22].

Technology, in practical terms, is a form of recipe for effectively performing a specific task. In this regulation, very important factors are not only the components, i.e., number, time, load capacity, capacity, etc., but also a very important factor such as the order and method of performing activities carried out within the process. The above-mentioned elements should constitute one whole, cooperate with each other, and strive to minimize work expenditure while maintaining or improving the quality of the tasks performed [10]. Therefore, it would be necessary to explain what internal transport technology is. In the broadest sense, it is a method of implementing transport and storage processes that directly result from the logistic task [8], [14]. This method considers the relationships between:
- frequency of load streams (described in terms of subject matter, number, sending and receiving points, available time and buffering places);
- information streams related to the flow of materials;
- performance of the elements of the transport and storage system (due to type
- and parameters of the means of transport, as well as the efficiency of the people involved
- in the flow of materials and information);
- basic costs resulting from the operation of the means used.

Internal transport technologies include:
- Manual – people's work is supported by simple devices, the human factor is an important element. This technology is characterized by much lower efficiency and efficiency. It has significantly lower costs than the other two technologies. It is mainly used in smaller warehouses where automation is not economically justified. The use of manual technology results in lower unit costs resulting from the use of simple devices that do not require advanced software. The means of internal transport used are not very complicated to operate, so in most cases they can be repaired by operators. A permit to work with most devices is not required, which does not generate additional problems resulting from the need to have staff with special certificates or the need to invest in necessary courses. The cost of consumable parts is lower than in other technologies. This technology has a large error factor (including human errors, absenteeism, accidents at work).
- Mechanized – this technology is based on human work using devices. Operators of the trolleys used in this case are obliged to have permits to use the means. Operating costs are much higher than in manual technology. In most cases, support from specialists or external companies is necessary. The variety of equipment offered for this technology is an advantage because it offers a wide range of possibilities. Efficiencyand the efficiency of the internal transport process is much higher thanin manual technology – greater capacity and lifting capacity of means of transport. More advanced equipment is used here, which also requires staff with higher qualifications and the need to undergo specialized training. The use of this technology requires a larger warehouse thanin manual technology and it must be economically justified.
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It is therefore important to take into account the appropriate selection of storage technologies, including transport, when designing a warehouse. Transport technologies are a key factor influencing the organization of warehouse work, its efficiency, quality of work, reliability of task execution and costs.

2. Selection of internal transport technologies from a theoretical perspective

The proper functioning of a logistics facility in which internal transport plays a key role is determined by many factors. These include, among others, the selection of appropriate internal transport technology. What technology is and internal transport technology has been described previously. It is necessary to emphasize the relationship between the storage zone and internal transport, because the types of racks used in the storage zone will determine what means of internal transport will be used. Therefore, the selection of technology in this case should be considered jointly. Two common parameters will be: aisle width and storage height [14], [25]. Internal transport technologies are characterized by, among others: using specific means of transport. Due to the broad scope of this topic, the characteristics of internal transport means and their types will not be discussed for the purposes of this article. However, it is worth emphasizing that the appropriate selection of equipment for the implementation of the warehouse process (internal transport technology) is characterized by:
- required system performance;
- the size and ratio of human labor costs to equipment operation;
- the intensity of material flows handled in the system;
- forms and types of supported load units;
- technology of storage, offering materials and carrying out other activities in the zone, and therefore the limitations that exist for means of internal transport;
- technical condition of the substrate and type (floor);
- conditions in functional zones, work organization and occupational health and safety requirements (e.g. closed zones, frosty zones, work outdoors, at heights, with hazardous or chemical materials).

The choice of internal transport technology is closely related to the scale effect. This means that high material flow rates in warehouse facilities justify the use of transport technologies that are expensive to purchase and maintain. These technologies are most often more efficient and effective for the entire process. If a large number of activities are performed in a warehouse facility, even small time savings at each stage will collectively lead to large savings throughout the entire enterprise. If you expect high efficiency of the internal transport process, you should analyze the available and necessary data to properly choose between automatic, mechanized, and manual technologies. Before making a decision, a detailed analysis should be carried out regarding the structure and flow of materials in the warehouse (or in a specific functional zone) as well as the costs of human labor and equipment. Considering all the described aspects, it is noted that the selection of internal transport technology is a complex process and difficult to implement. However, properly organized internal transport should ensure the handling of flows in the warehouse, minimizing the consumption of means of transport and the time of tasks performed, as well as rationalizing operational and operational costs.

In the era of constant technological progress, many enterprises decide to take a bold step involving a large investment in automation. Is this step always, correct? Before making such an important decision, a broad analysis should be carried out, including several criteria and factors. Factors [14]:
- availability of technology on the market;
- selection of the method of submission/assembly/issuance;
- type of equipment in warehouse facilities,
- parameters, advantages, disadvantages, and general guidelines regarding the possibility of using particular technologies.

The criteria include [1], [2], [5], [6], [14], [15], [26]:
- technical criteria:
  - area of the warehouse facility (large/small);
  - the volume of the warehouse facility (small resulting from the limitations of low-rise buildings or large without limitations);
  - o capacity of functional zones;
  - o process efficiency (maximizing the efficiency of processes implemented according to a specific technology – storage, picking, internal transport);
  - the level of process automation (determining the need to automate processes carried out in the logistics facility);
- economic criteria:
  - investment in technology (profitability ratio);
  - operational and operational costs (costs resulting from the use of

a given technology to carry out a logistic task, e.g., picking, relocation; and others);
- additional criteria:
  - selectivity of the assortment (determining whether access to each loading unit must be possible at any time, or only to at least one type of assortment);
  - o universality of technology (possibility to handle many different tasks using a given technological solution, use of internal transport means to perform many tasks in the warehouse, easy reconfiguration and expansion of internal transport systems);
  - about safety (not only of the employees themselves, but also of the devices they use).

The basic conditions for the automation of internal transport include: [15], [20]:
logistic form of materials – unification, repeatability, standard sizes, packages correctly and well secured;
- high-quality material carriers;
- volume of material flows – criterion of profitability of using automatic technology;
- justifying the use of automation in exchange for human work;
- high quality of logistics services – high price of the serviced products, goods requiring special conditions (e.g., medicines or electronics);
- special working conditions – e.g., low temperature, sterility, difficult access;
- low rate of assortment variability;
- possibility of integrating new solutions with existing systems
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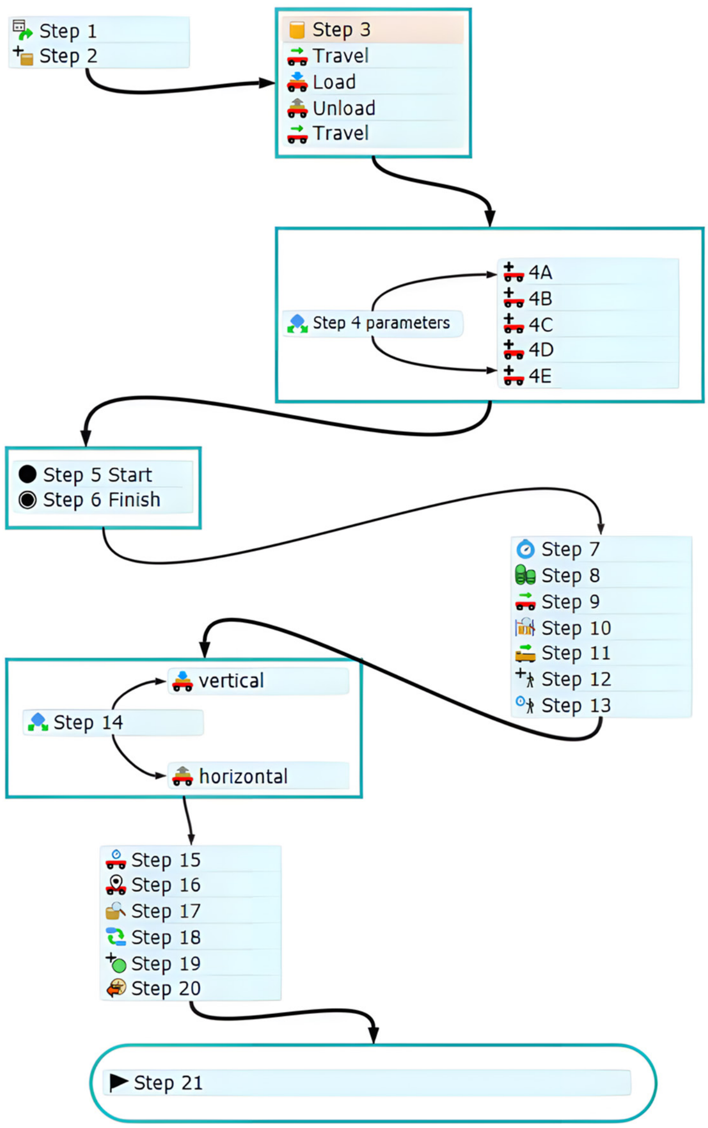
Now that you know many criteria and factors influencing the appropriate selection of internal transport technology, you should proceed to the next step. The next stage can be considered the development of steps for selecting the appropriate technology for the needs of a given enterprise. When developing such a sequence of steps that can be called an algorithm, it is important to make it as universal as possible and therefore applicable to various enterprises. The available literature contains algorithms for selecting technologies [13],[16],[17],[18]. The algorithm (Figure 1) for selecting internal transport technology developed by the authors [14] in the form of a sequence of activities is presented as follows:

Fig. 1. Algorithm



Source: own study based on [14]

Start

Step 1. Start of the process.

Step 2. Shaping the warehouse process – means describing how the warehouse process carried out in each logistics facility will work.

Step 3. Identification of a single transport task – in a given warehouse facility, many transport tasks may be carried out simultaneously or consecutively, one should select the most typical one and subject it to a broader analysis, it will constitute a kind of pattern.

Step 4. Identification of conditions imposed by technologies for the selected task – the following parameters describing the logistic facility should be defined:
- 4A width of working corridors;
- 4B required lifting height;
- 4C way of running devices (control);
- 4D work equipment;
- 4E automatic **solutions used.**

Step 5. Identification of movement starting points – factors closely related to the task carried out at the logistics facility should be precisely determined:
- single receiving location;
- a set of storage locations from which downloads can be made.

Step 6. Identification of movement endpoints – similarly to step 4, the tasks performed at the logistics facility should be specified in detail:
- single drop off point;
- a set of storage locations where storage can take place.

Step 7. Identification of the repeatability of the transport task – based on available historical data, determine the frequency with which the transport task will be repeated:
- high daily/hourly repeatability;
- low daily/hourly repeatability;
- no daily/hourly repeatability.

Step 8. Identification of the size of material flows on a given route (in step 2, a single transport task was determined). Then, you need to determine what amount – on the route being performed – will be realized in terms of material flow:
- significant/slight/insignificant.

Step 9. Identification of uniformity of material flow:
- uniform flows;
- grouped repetitive flows;
- irregular grouped flows;
- irregular flows.

Step 10. Identification of types of storage units (moved) – determine what type of units will be handled by internal transport means:
- one type of standard unit (e.g. pallet);
- many types of units (non-standard – picking);
- bulk materials (liquid, loose, etc.);
- materials requiring specialized manipulators.

Step 11. Identification of requirements regarding the level of automation – determining the possibilities of using and needs of automation in the logistics facility for the implementation of the selected logistics task:
- high level of task automation;
- low level of task automation;
- mechanical task;
- manual task.

Step 12. Selection of the method of moving the operator with the unit – determining how the operator will perform tasks in the logistics facility:
- device operator moved and lifted with the unit (direction and manual work, e.g., picking);
- device operator moved with the device (driving);
- device operated automatically or automatically (without operator participation).

Step 13. Identification of requirements for the universality of technology (change in the work area) – determining the possibility of using various means of internal transport or limiting the use of a small number of universal means, adapting to the surface and economic possibilities of the logistics facility:
- universal technology with flexible use and the ability to change the work area;
- specialized technology without the possibility of changing the area.

Step 14. Requirements regarding the method of movement – vertical/horizontal – determining the type of devices to be used:
- horizontal movement (lifting);
- vertical and horizontal movement (with lifting);
- vertical movement (only lifting, e.g., elevator).

Step 15. Identification of movement distance – determining how far internal transport means will move for a given task in the logistics facility:
- large (inter-departmental transfer);
- low (intra-zonal movement).

Step 16. Identification of movement and safety conditions – determining the basic conditions in which means of internal transport will operate in the logistics facility:
- temperature and humidity;
- precipitation and dust;
- type of surface (if required) and slope;
- employee and unit safety, exhaust emissions;
- equipment servicing conditions (poor/good).

Step 17. Identification of the need to track the flow of materials (automatic flow registration) – determining whether as the loading unit moves in the logistics facility, it is necessary to track it on an ongoing basis:
- unit tracking required;
- required unit tracking and identification (weight, dimensions, label);
- no requirement for tracking and identification.

Step 18. Identification of the possibility of substituting human and automatic work – in this step, the possibility of changing human work to automatic or vice versa should be analyzed. Having the required data, you should decide about selecting the appropriate solution for the logistics facility where the task is performed:
- high/low human labor costs;
- availability of qualified staffl

Step 19. Identification of available financial resources – in this step, all the above should be carefully analyzed and, having knowledge about the financial capabilities of the logistics facility, the final resources should be determined.

Step 20. Selection of selection criteria – each decision-maker will select variants based on different criteria, depending on the needs, financial possibilities, and the size of the flow of goods flows.

Step 21. End of the process.

Stop.

Having a tool in the form of an algorithm will make it much easier to choose the right technology. After determining the necessary parameters, proceed to the next stage, i.e. verifying whether the selected technology is appropriate or not. It is best to use simulation modeling for this purpose due to the wide possibilities and low costs of developing many models.

3. Computer simulation of the selection of internal transport technologies

Carrying out the described 21 steps is aimed at defining the factors, criteria, possibilities and needs of the examined enterprise and synthesizes the features of the examined object. These are data that constitute a source of information for simulation modeling. There are many computer simulation programs on the market. One of them is FlexSim. This program allows you to model many solutions and visualize them in 3D. The main function of the program is to shape, design and organize the model under study. Once you have defined the data needed for the algorithm, you should move on to testing in IT conditions. For the purposes of this article, a computer simulation was performed. The selection of technology (manual, mechanized) for an enterprise dealing with the storage of goods was assumed as input data, and one process was adopted for the research: transport between the storage zone and the picking zone.

Then the transport process lasts 8 hours, and in the storage zone there are 9 racks (each one holds 480 pieces of goods, and individual racks hold packages of different weights – table 1), the next data is three storage fields (SA1-3) understood as three customers, one picking list for each customer (the same for all). To calculate the time needed to pick up one parcel of a specific weight and the maximum number of parcels per1 transport, data resulting from the specificity of the examined means of transport were adopted (hand pallet truck and forklift – table 2).

Table 1. Data adopted for simulation

Rack number	Weight of one package (kg)	Time to pick up one parcel [s]	Maximum number of parcels per transport [pcs.]
1	30	59	16
2	35	68	16
3	40	75	11
4	45	80	11
5	50	92	9
6	55	103	8
7	60	115	7
8	65	129	6
9	70	137	6

Source: own study

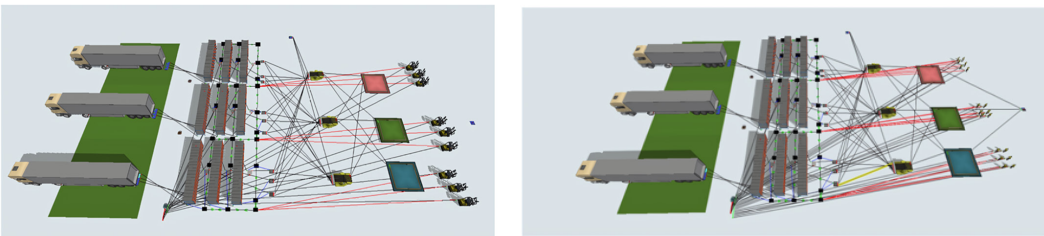
Table 2. Trolley parameters

Parameter name	Forklift	Pallet truck
Nominal load capacity	2000 kg	1500kg
Movement speed	1,4 m/s	1,21 m/s
Maximum number of parcels picked up in one run	15 pcs.	5 pcs.

Source: own study based on: [27],[28].

A very simple model was adopted as the completion order. Internal transport means are to deliver 10 pieces of each product to each storage area. Therefore, ultimately, each storage field should receive 90 pieces of packages, which is equivalent to the execution of one full picking order. All data were entered into the FlexSim computer program and simulation studies began. The designed models are presented in Figure 2, the first one on the left with mechanized technology, and the second one with manual technology.

Fig. 2. Visualization of the tested models in the FlexSim program



Source: own study.

After starting the simulation, the process of delivering the indicated parcels by internal transport to the designated storage areas begins. During the examined period (8-hour work mode was adopted) for manual technology, the execution of picking orders is presented in Table 3.

For mechanized technology, the execution of picking orders is presented in Table 4.

Table 3. Execution of picking orders – manual technology

Number SA	Completed assembly orders [pcs.]	Number of parcels in the storage area
SA1	23	2070
SA2	28	2520
SA3	23	2070

Source: own study

Table 4. Completion of the assembly order – mechanized technology

Number SA	Completed assembly orders [pcs.]	Number of parcels in the storage area
SA1	19	1710
SA2	32	2880
SA3	25	2250

Source: own study.

Analyzing the data presented in Tables 3 and 4, it is noted that in total, mechanized technology performed more work under the same assumptions. In total, 2 more picking orders were completed using this technology compared to manual technology. A significant advantage of manual technology was that the work performed using it was more uniform, in this case the number of completed orders and the number of products in the storage areas are very similar. The situation is completely different in the case of mechanized technology – despite the larger number of picking orders completed, the work was less uniform. In storage area 1, 19 picking orders were completed, i.e., 1,710 items of assortment, and in storage area 2–32 picking orders, i.e. 2,880 items. The difference is 1170 pieces. It could therefore be assumed that the right choice would be to use mechanized technology in each case, because it completed more orders at the same time, but will this decision really be the right one? At this stage of considerations, you should think the decision over carefully. The differences between manual and mechanized technology in the examined case are very small; of course, the results will always depend on the data adopted, the needs of the enterprise and its capabilities. In such a situation, it is worth assigning weights to the factors that are considered. In the examined case, is it more important to perform two more picking orders or to ensure the uniformity of the tasks performed? It may be important to determine the priority of a specific client, which for the purposes of the study was defined as a set aside field. This analysis should be broad and thorough because deciding will have long-term effects.

Summary

Internal transport is a very complex process. Nowadays, there is a desire for continuous automation. Of the manual, mechanized and automatic technologies available on the market today, a significant number of enterprises use – or plan to use – automation. Whether these decisions are right or not should be decided by a broad and thorough analysis. The aim of the article was to analyze and evaluate the possibility of using simulation software to support decision-making regarding the selection of internal transport technologies in a warehouse. The conducted research indicates that the proposed tools may be a good way to make the right decision regarding the appropriate selection of technology. Please remember that this is not an easy task. It is important not to succumb to trends, but only to the needs of your own company. In the era of growing competition, everyone wants to perform their tasks quickly, so that the final customer is satisfied and the goods he ordered reach his home as quickly as possible. The article discusses theoretical aspects regarding internal transport and technology, proposes the use of a selected algorithm and conducts research. Their analysis did not provide a clear answer as to what technology should be used for the case under study. To make this decision, it would be necessary to finally determine what criteria are most important for the example being examined. If a mechanized technology solution is chosen, the company can complete 2 more picking orders compared to the manual one (in total – manual 74 orders, mechanized 76 orders). Due to the small difference in the execution of picking orders, deciding may be difficult. This makes it necessary to further develop simulation models with new constraints. However, this confirms the adopted working hypothesis, indicating that it is possible to support the decision-making process regarding the selection of transport technology using simulation software. Moreover, the developed algorithm and its practical implementation can be used by warehouse designers to cost-free check their solutions and selected storage and transport technologies. However, further research directions should be focused on modeling subsequent models in the FlexSim program, searching for a dominant solution.

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