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SELECTION OF MANUAL ORDER PICKING CONCEPTS IN A WAREHOUSE BY MEANS OF SIMULATION TOOLS

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Abstract. Along with the lengthening of a product's path from a producer to a customer, and with speeding up the flow of goods, information and finance in the chain of supply, the places where these flows and streams could be regulated are required. The control over the flow of material and non-material goods and the increase of the supply chain's effectiveness are possible thanks to the units called logistic hubs, which are mainly represented by a warehouse. In this paper, the authors analyze the influence of the three most popular strategies of warehouse worker's movements through the warehouse on order picking time. The simulation was carried out on the example of a real distribution warehouse which is owned by one of the leading discount stores networks in Poland. In the research, a special computer software, written for the purpose of the research, was used. This software enables matching the best order picking concept to the conditions of a given enterprise.

Keywords: logistics, order-picking, warehouse management, simulations.

JEL Classification: C63.

1. Introduction

Globalization processes and the increase of competition have caused a situation where companies started to look for solutions and strategies allowing them to develop and expand on the market.

M.E. Porter believes that the main source of competitive advantage is not the general state of a business entity, but the effectiveness of different types of activities which are done to supply its product on the market. Such

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activities create a chain of value (Porter, 2001). Globally growing competition, which took place in the 1980s, forced businesspeople to offer low costs, high quality, and reliable products, at the same time being more flexible. In order to do this, some new management concepts were used. They aimed at improving production efficiency, the flow of goods through a supply chain, and reducing stocks in every logistic hub.

In the modern logistic system, every manipulation of materials is subjected to detailed verification at the stage of planning. The small movements of goods for short distances, which happen in the premises of a given building (warehouse, production plant), and between the building and transport intermediary, are starting to play a very important part. The order picking problems are especially visible in logistic centers which are becoming more and more important in modern supply chain management. They focus on finding the best possible way to locate the goods in a given space, using the limited capacity of the building to the utmost and reducing the number of manipulations with a given product. Logistic managers manage the logistics centers so as to use the available storage capacity to the utmost. At the same time, they need to provide the right access to stored goods and have them well protected. This results in the fact that storage space is no longer treated as an area with specific measurements but as a place where there are proper conditions for storing goods.

A report prepared by A.T. Kearney for the National Council of Physical Distribution Management (NCPDM) (Mentzer, Ponsford, 1991) showed that costs connected with logistics equals 21% of American GDP, whereas 28% of these costs are generated by storing and order picking processes. The research, carried out in 1984, started a hot debate and created a need to lower logistics costs, which have been increasing along with market development.

2. Order picking systems

Order picking is a process of logistic, operational and organizational activities. It is comprised of the combination of specific subsets (goods), from the prepared set (assortment), on the basis of order information in the form of commission. There also occurs a change of a specific state of stored goods into a characteristic state of released goods (Fijałkowski, 2003; Ghiani, 2004). In other words, order picking is searching for and completing, from storage places in a warehouse, specific goods which are on the order list placed by a customer (Petersen, Aase, Heiser, 2004). According to the research, the transfer is the most laborious activity. It can be defined as covering a given distance between the points of taking the order and the places of picking up and releasing of goods (Kłodawski, Jacyna, 2009).

The work of scientists and researchers aims at speeding up and reducing the costs of completing the order. So as to meet the requirements of general system efficiency, three basic questions which determine the overall time of the order picking process, need to be answered. First of all, how to pick up goods (complete), secondly, how to store (stock up), and finally how to move to get the ordered commodity?

Picking policies focus on the division of labor among workers, so that the time of picking the goods, according to the order picking list, is as short as possible.

In accordance with the division made by Ackerman, there are three approaches in order picking policy: strict order picking, batch picking and zone picking (Ackerman, 1990). Strict order picking assigns an individual worker who directly completes a single order. Batch picking assigns a single warehouse worker to the bigger number of orders during the order picking route, whereas zone picking assigns a warehouse worker to one zone where he or she is responsible for the goods which are on his or her order picking list (Petersen, 2002).

We can distinguish three types of zone picking: sequential zone, batch zone and wave zone. Sequential zone picking is typical for one order which is completed at a single carrier. In this type, the carrier is transported by means of a sequential vehicle from one zone to another, and in every zone a warehouse worker, responsible for a given area, completes the order which is assigned to a given part. In batch zone picking, the order is picked separately but simultaneously in every picking zone, and at the end of the process it is put in to one complete whole which goes to the client. Wave picking is a special type of batch zone picking in which a warehouse worker picks some large batches of goods and his or her actions are not based on the number of products from the order list but on the order picking time (usually from 30 minutes to 2 hours). After the process of continuous order picking, which is discontinued only for unloading a full carrier, there is a consolidation process of a given order which is done by the workers on the basis of goods brought in (Frazelle, Apple, 1994).

The way of goods storage, i.e. storage policies, is another topic analyzed and considered by scholars and logistic practitioners. Storage policies deal with assigning some specific locations for given goods (storage). There can be some different ways of storage. The first one is called random storage. This approach is based on storing the goods in a warehousing space in which there is a free space for it. In this way the time is reduced which is needed for putting the product down, yet it increases in the order picking process.

The second approach is based on allotting a specific place in a warehouse, which can be distinguished – taking into account several factors – to a given good. Storing goods on the same carrier (euro-pallet) together is the first factor. This is very convenient for technological reasons as it helps to optimize the storage space on the pallet rack. The second factor comes down to a simple rule according to which goods with the fastest rotation have to be located as close as possible to the warehouse's exits so as to minimize the order picking time (Ghiani, 2004).

Routing policies are the last major point in the order picking research. The most important point of these studies is to find some ways to minimize the distance that warehouse workers have to cover on a route in the order picking process. Out of different algorithms which try to solve the problem of minimizing and shortening the length of the order picking route, heuristics algorithms are the most popular. Their universality results from the fact that they are very easy to implement and have similar results to algorithms with accurate results (Ratlif, Rosenthal, 1987). The limitations with using algorithms with accurate results are caused by the too big number of variables, and difficulties in creating new models for such a varied order picking lists.

3. Heuristics approach outlining the order picking routes

S-shape (traversal strategy), midpoint strategy and return *strategy* are the main heuristics methods of outlining the order picking routes. The S-shape method is one of the simplest approaches to outline a route for the person who works on completing the order. A warehouse worker who works according to this strategy moves between the pallet racks, where the commodities for order picking are placed in a particular way, starting the route at the beginning of the passage and proceeding to the next one only when all goods have been collected from the previous passage. The whole order picking route resembles the letter "s", which is presented in Fig. 1.

In Fig. 1, 2 and 3, the letter D stands for the start and the end point, where the warehouse worker starts and finishes the route in which he or she picks the goods (letter P) designated for shipment.

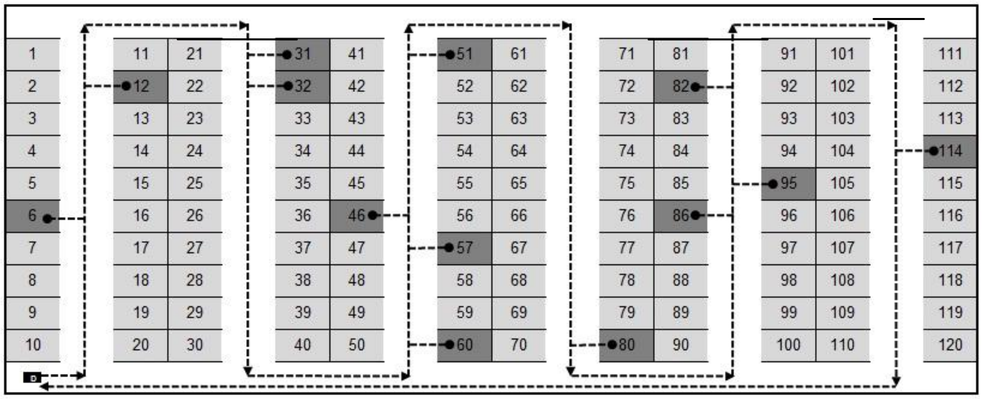

Fig. 1. S-shape strategy (traversal strategy)

Source: own elaboration on the basis of (De Koster, Le-Duc, Roodberger, 2007).

Midpoint is another strategy outlining the order picking route. This approach divides the warehouse into two zones. Here, the warehouse worker moves through the passage only to the middle of the warehouse, which is a border point of the first zone. The remaining commodities, which are located in the second zone of the warehouse, are picked on his or her way back. The outline of the midpoint method is shown in Fig. 2.

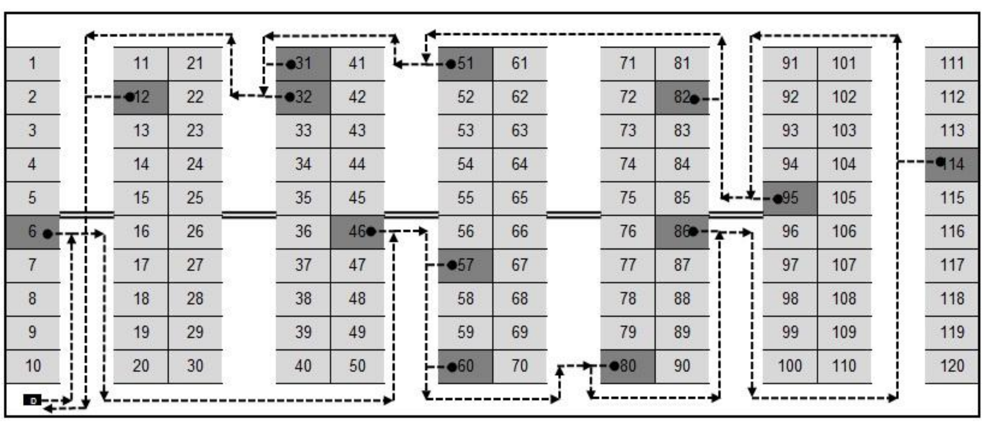

Fig. 2. Midpoint strategy

Source: own elaboration on the basis of (De Koster, Le-Duc, Roodberger, 2007).

The return strategy is the last heuristics approach outlining the order picking route in a warehouse described in this paper.

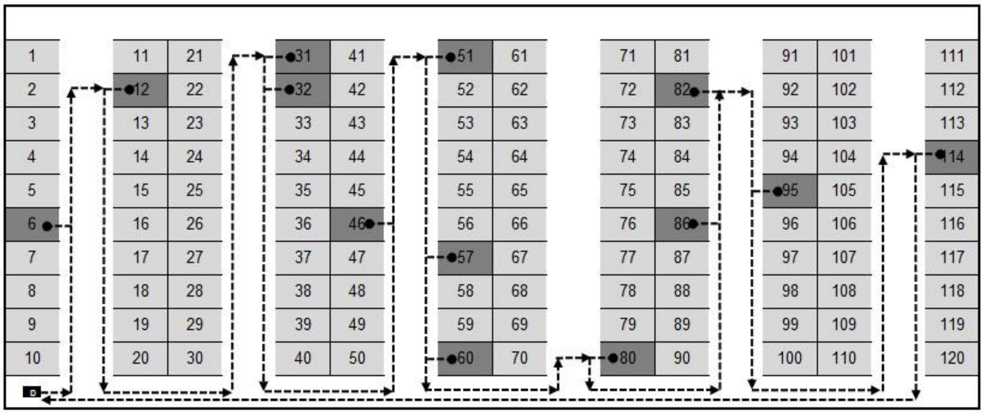

Fig. 3. Return strategy

Source: own elaboration on the basis of (De Koster, Le-Duc, Roodberger, 2007).

According to this strategy, a warehouse worker moves along the passage up to the last commodity which is itemized on the order picking list and located on the racks which are adjacent to the passage. After collecting the products, a warehouse worker goes back to the main passage which is at right angles to the racks and proceeds to the next items on the order picking list following the above-mentioned rule.

Heuristics algorithms outlining the order picking routes are especially popular in some warehouses where the order picking process is done by "humans". The simplicity of their implementation and correspondence in the results to the algorithms with accurate results are the main reasons for this situation (Ratlif, Rosenthal, 1987). The limitations of using accurate algorithms in the warehouses, where the order picking process is done by hand, are caused by the fact that new mathematical models need to be built all the time, and there are a lot of variables which one has to take into consideration while doing calculations. Furthermore, a warehouse worker would have to learn the new routes, which would change along with the order picking list all the time. Owing to heuristics algorithms, a warehouse worker can learn certain habits while moving through the warehouse. These habits are unchanging, and in this way the threat of possible mistakes is minimized. A completely different situation occurs in automatic warehouses of the AS/RS type, where the algorithms with accurate results are in the lead. In these warehouses the order picking systems are supported by computers with a big computing power. Computers are able to outline the optimal route for a given order picking list in a very short time. Due to the fact that the order picking process is done automatically by a machine, which moves to the places indicated by the main computer, mistakes are almost impossible to make.

4. Blocking situation in aisles

A situation in a warehouse where forklift trucks block one another while order picking is a common problem which logistic managers need to solve. A blocking situation happens when the space for forklift trucks movement is not enough and the vehicles cannot pass or overtake each other freely. It happens very often that the space between the pallet racks is enough to provide work for several trucks at one time, but restrictive rules of industrial safety do not allow this to happen. They state that a safe distance between workers should be provided.

In the books about this subject (Furmans, Huber, Wissen, 2009), as well as in practice, there are two blocking situations of forklift trucks that can be observed.

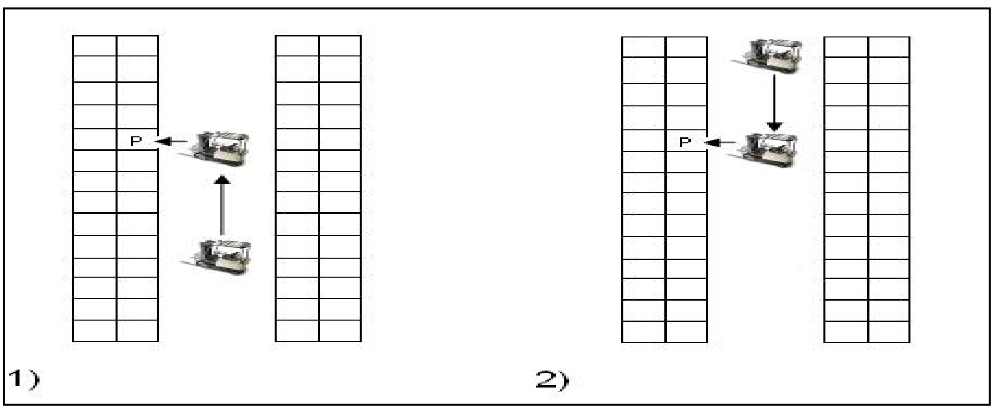

Fig. 4. Exemplary blocking situation

Source: own elaboration on the basis of (Furmans, Huber, Wissen, 2009).

In the first situation, a forklift which stopped to pick the goods from the list, cannot make way for the forklifts moving in the same direction, which want to pick goods located in other parts of the warehouse. The reason for the second situation is similar; however, a forklift cannot make way for the trucks moving in the other direction. In both examples, the problem is based on the time needed for picking the commodity from a storage place. It is easy to notice that a longer picking time creates more frequent situations where trucks get stuck in a so-called “traffic jam”.

5. Description of the research

The research was carried out in a warehouse owned by one of the biggest discount store chains in Poland. It is one of the logistics chains owing to which it is possible to receive deliveries from different companies, consolidate them, divide them and send them according to the orders made by clients. In this case, clients are individual stores located in different parts of the Lower Silesian Voivodship (*województwo dolnośląskie*).

In the warehouse, one of the subzones designed for storing beverages, was analyzed in detail.

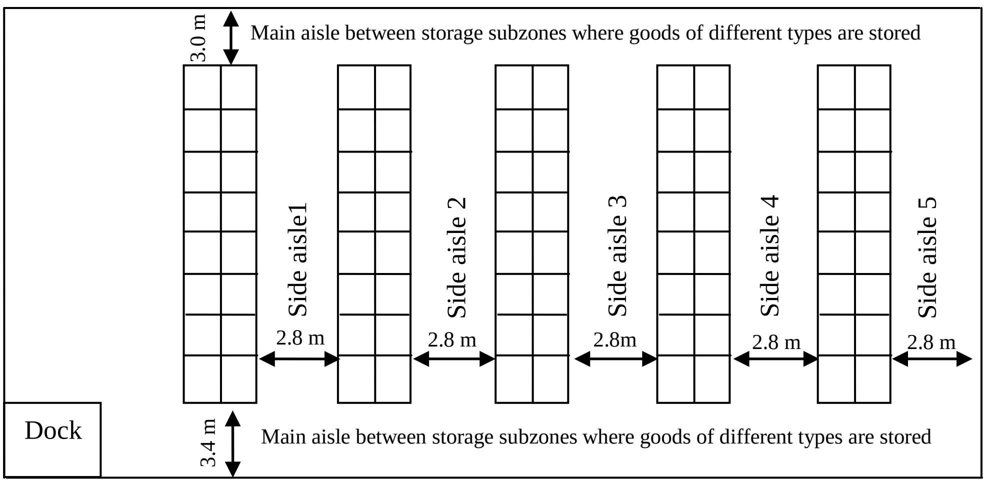

Fig. 5. The plan of warehousing zone for the beverages

Source: own elaboration.

The zone consists of 14 pallet racks. Each rack is 46.5 meters long. 14 different products (material indexes) are stored in each rack. Order picking is done from the lower level of the rack, whereas in the three remaining upper levels the materials which later will be moved to the lower level are stored. The warehouse operates on two shifts. During the first shift the completion of orders to different stores is carried out. During the second shift the goods are received and the order picking zone (the lowest level of the rack) is topped up. The order picking process, taking place during the first shift, was analyzed. The main objective of the experiment was to examine the influence of the forklift truck movement method in a warehouse on the time of completion of the orders made by individual stores.

The situation in the warehouse is difficult to describe by means of empirical models and hard to reconstruct by simulation methods as warehouse workers were moving through the warehouse in a disorganized way and different for every order. The lack of one unified routing strategy caused numerous collisions and lowered work efficiency. Warehouse workers use some simple technical solutions in their work, which prevent us from introducing some advanced methods of controlling product flow in a warehouse.

In the paper, the authors used norms of forklift truck's work, presented by Fijałkowski (Fijałkowski, 2003), as well as their own calculations done for the purpose of the research. A very important piece of information used in this paper is the fact that the average number of material indexes on one order picking list equals 11.

Table 1. Forklift truck's working time norms

Activities	Symbol	Unit	Time (min)
Acceleration after stop (empty)	AE	Full period	0.0300
Acceleration after stop (loaded)	AL	Full period	0.0300
Speed 3 km/h) – loaded truck	FL	Per 1 meter	0.0200
Speed 3 km/h) – empty truck	FE	Per 1 meter	0.0200
Stop (empty truck)	SE	Full period	0.0200
Stop (loaded truck)	SL	Full period	0.0360
Turn left (moving forward)	TFL	Full operation	0.0550
Turn right (moving forward)	TFR	Full operation	0.0550
Putting a pallet on the forks	NP	Full operation	0.1333
Scanning and putting the good on the pallet	CP	Full operation	0.1733
Putting loaded pallet on the storing field	OP	Full operation	0.2000
Laminating the pallet, sticking and printing the label	OFP	Full operation	0.3533
Moving back (0.8 m)	RE	Per 0.8 m	0.0750

Source: own elaboration on the basis of (Fijałkowski, 2003).

The location of the pallet racks, length and width of aisles, size of shipment zone (Fig. 5, Dock) are not considered.

6. Empirical example – simulation

The order picking problem can be relatively easy to simulate by the computer. The issue was discussed by many authors from around the world. Fijałkowski (Fijałkowski, 1987) gives precise formulas by which the forklift's work time can be designated. But forklifts sometimes can interfere with each other's work. Few authors dealt with the problem of blocking. In this case, the matter is very complicated and requires the use of special computer software. The authors created a computer simulator of the warehouse and made the calculations presented below.

The beverage subzone of the distribution center, whose work the authors analyze, takes orders for 8 hours a day. Their average numbers at different times of day are given in Table 2.

The simulation took 1050 days, during which forklifts completed 98,433 orders and collected 1,082,763 goods. The authors have assumed, as in the queuing systems, that orders appear according to exponential distribution. The average times obtained from the simulation may thus differ slightly from the real data. Orders are accepted until 16:00, but forklifts can work longer – up till when the last item is taken.

Table 2. The average time of orders arrival
(real data and the values obtained by simulation)

Time period	The average time between two consequent orders (real data)	The average time between two consequent orders (values obtained by simulation)
8:00-9:00	03:31	03:30
9:00-10:00	04:15	04:14
10:00-11:00	04:01	03:57
11:00-12:00	06:59	06:49
12:00-14:00	10:12	10:05
14:00-15:00	05:01	05:02
15:00-16:00	04:05	04:07
Whole workday (8:00-16:00)	**06:02**	**05:58**

Source: own elaboration.

Table 3 contains the average distance traveled by the forklift and the number of actions performed during the completion of one order. The forklifts definitely drove the shortest distance by the midpoint strategy. This is because in this strategy, after downloading the last item, the forklift is usually located close to the dock. The smallest number of turns is made for the shape and return strategy. The quite time-consuming process of turning back most rarely occurs for the s-shape strategy. Despite this, the shortest completion time(regardless of the number of forklifts used) was reached with the midpoint strategy (Tables 4-6). The result for five forklifts is two minutes better than with the s-shape strategy and six minutes better than with the return strategy. For a smaller number of forklifts, the differences in the picking time grow significantly. Table 6 shows the cumulative distribution function (CDF) of order picking times for the three strategies.

The waiting time of the commencement of the contract when using five forklift trucks is quite short: the smallest value is 2 minutes 36 seconds for the midpoint of the strategy. In practice, the number of forklifts operating in the subzone is variable (trucks move between subzones). The authors in their simulation assumed a fixed number of forklift trucks. Under this assumption, reducing the number of forklifts to four or three causes a significant increase in waiting time and the execution of the contract.

Table 3. Distance traveled and number of maneuvers performed during the completion of one contract

Picking strategy	The average distance traveled during the completion of a contract [m]	The average number of turns during the completion of a contract	The average number of turns back during the completion of a contract	The number of goods taken when picking one order
S-shape	617.16	15.36	0.65	11
Midpoint	528.15	18.02	7.12	11
Return	661.21	15.36	7.79	11

Source: own elaboration.

Table 4. Picking times for 5 forklift trucks

Picking strategy	The average total lead time and its standard deviation	The average lead time and its standard deviation (only forklifts work time)	Average waiting time for the start of the contract	Completion time of the last order (average)	Completion time of the last order (max)
S-shape	20:29/6:28	16:50/1:21	0:03:39	hour 16:17:12	hour 16:55:21
Midpoint	18:25/5:05	15:49/1:06	0:02:36	hour 16:14:55	hour 16:45:37
Return	24:28/9:20	18:25/1:50	0:06:03	hour 16:21:20	hour 17:09:51

Source: own elaboration.

Reducing the number of forklift trucks will save money, but on the other hand, the longer work time increases the costs of the warehouse. Determining the optimum number of forklifts is not the subject of this work. This problem can be treated as a multi-criterial decision making problem and will be a subject of further study of the authors.

Table 5. Picking times for 4 forklift trucks

Picking strategy	The average total lead time and its standard deviation	The average lead time and its standard deviation (only forklifts work time)	Average waiting time for the start of the contract	Completion time of the last order (average)	Completion time of the last order (max)
S-shape	29:27/15:10	16:49/1:21	0:12:37	hour 16:25:56	hour 17:29:47
Midpoint	25:04/12:09	15:49/1:06	0:09:15	hour 16:21:44	hour 17:21:14
Return	37:57/20:27	18:25/1:49	0:19:32	hour 16:34:15	hour 17:50:47

Source: own elaboration.

Table 6. Picking times for 3 forklift trucks

Picking strategy	The average total lead time and its standard deviation	The average lead time and its standard deviation (only forklifts work time)	Average waiting time for the start of the contract	Completion time of the last order (average)	Completion time of the last order (max)
S-shape	1:05:38/36:18	16:49/1:21	0:48:49	hour 17:14:13	hour 19:47:42
Midpoint	53:11/30:41	15:48/1:06	0:37:23	hour 16:54:17	hour 19:08:38
Return	1:28:06/45:26	18:24/1:49	1:09:42	hour 17:54:15	hour 20:55:10

Source: own elaboration.

Tables 7-9 contain the daily working and idle times of forklifts (inactivity relates to eight hours of taking orders) and stop times due to the mutual blocking of the forklift trucks. The shortest time and longest idle time is for forklift trucks using the midpoint strategy. The blocking problem is least for the s-shape strategy, although the blocking times for all three strategies are very small. You could say that the problem of blocking the forklifts does not exist. This is because the picking times are short. The authors suspect that this problem can occur to a greater extent in high bay warehouses.

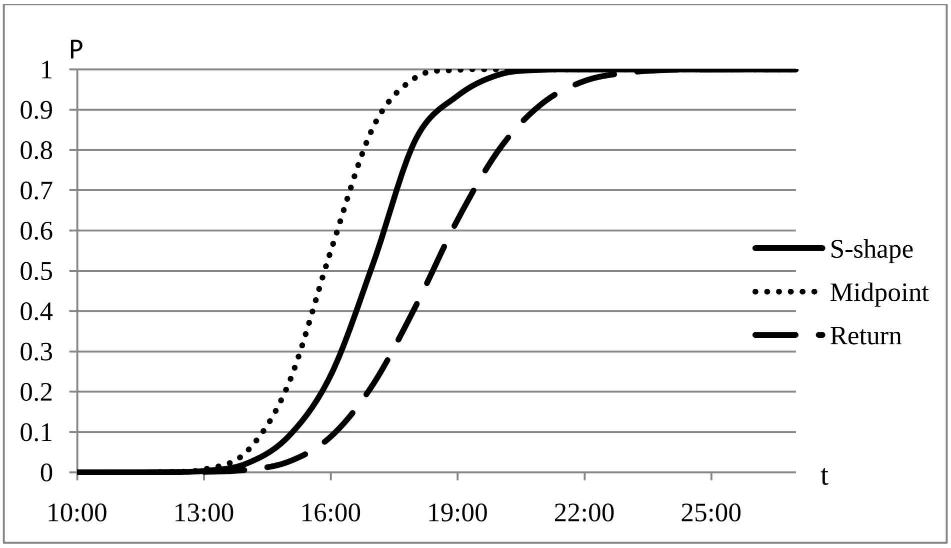

Fig. 6. Cumulative distribution function of order picking times (only forklifts work time)

Source: own elaboration.

Table 7. Working, waiting and blocking times for 5 forklift trucks

Picking strategy	Average daily work time and its standard deviation	Average daily idle time (waiting to order) and its standard deviation	Average daily blocking time of one forklift
S-shape	5:15:29/1:11:37	2:54:44/1:10:12	0:00:41
Midpoint	4:56:32/1:15:20	3:11:52/1:14:11	0:00:50
Return	5:45:19/1:05:34	2:28:25/1:03:38	0:01:16

Source: own elaboration.

Table 8. Working, waiting and blocking times for 4 forklift trucks

Picking strategy	Average daily work time and its standard deviation	Average daily idle time (waiting to order) and its standard deviation	Average daily blocking time of one forklift
S-shape	6:34:15/54:10	1:45:19/51:14	0:00:44
Midpoint	6:10:33/56:19	2:05:14/54:10	0:00:55
Return	7:11:26/51:31	1:15:50/46:27	0:01:22

Source: own elaboration.

Table 9. Working, waiting and blocking times for 3 forklift trucks

Picking strategy	Average daily work time and its standard deviation	Average daily idle time (waiting to order) and its standard deviation	Average daily blocking time of one forklift
S-shape	8:45:26/52:01	0:23:05/25:33	0:00:45
Midpoint	8:13:47/50:01	0:35:13/33:01	0:00:57
Return	9:34:48/56:07	0:13:12/15:22	0:01:23

Source: own elaboration.

Tables10-12 contain the results of a more detailed comparison of strategies. Of particular interest seems to be comparing two of the best strategies: midpoint and s-shape. 85.94% of orders executed in accordance with the midpoint strategy are performed more quickly, while 13.57% of them are slower than if the completion was carried out according to the s-shape strategy. The advantage of the s-shape strategy is very small – there is no contract that would have been completed at least 5 minutes faster than the midpoint of the strategy. 10.14% of the orders in the case of the midpoint strategy are at least 5 minutes shorter than for the s-shape strategy. Several orders have been made even with a majority of more than 20 minutes.

Table 10. Comparison of the time of execution of orders for the midpoint and s-shape strategy for five forklift trucks

Strategies compared	Orders executed faster	Orders executed faster by at least one minute	Orders executed faster by at least two minutes	Orders executed faster by at least five minutes
S-Shape vs. midpoint	13.57% (13,358)	3.28% (3,232)	0.47% (463)	0.00% (0)
Midpoint vs. s-shape	85.94% (84,591)	64.40% (63,393)	40.29% (39,659)	10.14% (9,982)
Strategies compared	Orders executed faster by at least ten minutes	Orders executed faster by at least twenty minutes	Orders executed faster by at least thirty minutes	Total number of orders
S-Shape vs. midpoint	0.00% (0)	0.00% (0)	0.00% (0)	100.00% (98,433)
Midpoint vs. s-shape	1.43% (1,404)	0.01% (6)	0.00% (0)	100.00% (98,433)

Source: own elaboration.

When comparing the midpoint or s-shape strategy with the return strategy, the dominance of the former over the latter is even more evident. There are orders for which the return strategy gives worse results by more than half an hour.

Table 11. Comparison of the time of execution of orders for the return and s-shape strategy for five forklift trucks

Strategies compared	Orders executed faster	Orders executed faster by at least one minute	Orders executed faster by at least two minutes	Orders executed faster by at least five minutes
Return vs. s-Shape	6.97% (6,857)	1.81% (1,779)	0.32% (313)	0.00% (0)
S-Shape vs. return	92.97% (91,509)	80.99% (79,719)	63.19% (62,202)	26.78% (26,357)
Strategies compared	Orders executed faster by at least ten minutes	Orders executed faster by at least twenty minutes	Orders executed faster by at least thirty minutes	Total number of orders
Return vs. s-Shape	0.00% (0)	0.00% (0)	0.00% (0)	100.00% (98,433)
S-Shape vs. return	9.11% (8,963)	0.68% (665)	0.01% (5)	100.00% (98,433)

Source: own elaboration.

Table 12.Comparison of the time of execution of orders for the midpoint and return strategy for five forklift trucks

Strategies compared	Orders executed faster	Orders executed faster by at least one minute	Orders executed faster by at least two minutes	Orders executed faster by at least five minutes
Return vs. midpoint	2.44% (2,406)	0.35% (348)	0.02% (20)	0.00% (0)
Midpoint vs. return	97.52% (91,509)	90.84% (79,719)	78.87% (62,202)	41.95% (26,357)
Strategies compared	Orders executed faster by at least ten minutes	Orders executed faster by at least twenty minutes	Orders executed faster by at least thirty minutes	Total number of orders
Return vs. midpoint	0.00% (0)	0.00% (0)	0.00% (0)	100.00% (98,433)
Midpoint vs. return	17.98% (17,696)	3.76% (3,697)	0.62% (613)	100.00% (98,433)

Source: own elaboration.

Table 13 presents the results of comparing the execution times of orders for the best midpoint strategy with five, four and three forklifts. Interestingly, increasing the number of forklift trucks can increase the time of collecting goods. For example, increasing the number of forklifts from four to five means that 67.42% of the orders are faster, but 7.11% are slower. Almost all orders are only seconds slower. Indeed, this phenomenon is caused by blocking of forklift trucks.

The biggest advantage occurs with the addition of the fourth forklift (up to 54.47% of orders are executed faster by at least 20 minutes and 12.15% up to an hour). Adding a fifth truck will accelerate a 20-minute delivery time for only 9.22% of the orders.

Table 13. Comparison of the execution times of orders for the midpoint strategy for 5, 4 and 3 forklift trucks

Strategies compared	Orders executed slower by at least one minute	Orders executed slower	Orders executed at the same time	Orders executed faster	Orders executed faster by at least one minute	Orders executed faster by at least two minutes
Midpoint 5 forklifts vs. midpoint 4 forklifts	0.00% (3)	7.11% (6,994)	25.48% (25,076)	67.42% (66,363)	57.20% (56,308)	53.05% (52,221)
Midpoint 5 forklifts vs. midpoint 3 forklifts	0.00% (2)	1.97% (1,936)	7.97% (7,845)	90.06% (88,652)	87.79% (86,417)	86.79% (85,426)
Midpoint 4 forklifts vs. midpoint 3 forklifts	0.00% (0)	1.95% (1,916)	8.01% (7,885)	90.04% (88,632)	87.13% (85,764)	85.53% (84,185)
Strategies compared	**Orders executed faster by at least five minutes**	**Orders executed faster by at least ten minutes**	**Orders executed faster by at least twenty minutes**	**Orders executed faster by at least thirty minutes**	**Orders executed faster by at least one hour**	**Total number of orders**
Midpoint 5 forklifts vs. midpoint 4 forklifts	41.56% (40,912)	26.32% (25,912)	9.22% (9,072)	3.14% (3,090)	0.01% (8)	100.00% (98,433)
Midpoint 5 forklifts vs. midpoint 3 forklifts	83.26% (81,958)	75.93% (74,740)	60.42% (59,473)	48.08% (47,328)	19.97% (19,660)	100.00% (98,433)
Midpoint 4 forklifts vs. midpoint 3 forklifts	80.74% (79,474)	72.28% (71,150)	53.47% (52,629)	40.14% (39,508)	12.15% (11,955)	100.00% (98,433)

Source: own elaboration.

7. Conclusions

The research which was carried out shows how big an influence the choice of appropriate order picking concepts has on the overall order picking time in a warehouse. Heuristics methods provide an organized flow of goods through a logistic hub and help to manage the work of warehouse workers. The described methods are often used in warehouses where the human factor plays an important role in order picking. Thanks to different devices which improve work, e.g. WMS systems, tablets, showing exact spots where goods should be picked, mounted on forklifts, etc., it is possible to use other heuristics methods and optimize the order picking processes in a warehouse (the abovementioned methods are going to be the subject in future papers).

The software which was created enables us to consider different order picking variants in a warehouse for different logistic hubs as well as consider different internal and external conditions and the factors having an influence on a given process. Simulation methods help to make a decision concerning designing, managing and doing various warehouse activities (Petersen, Aase, Heiser, 2004), which will be the subject of further research conducted by the authors.

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