IMPROVING S-SHAPE ROUTING STRATEGY FOR ORDER PICKING

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Abstract

The order picking in warehouses is the process of retrieving items from different storage locations according to customer orders. It is often the most consuming processes regarding workforce engagement in warehouses and significantly affects the wholesale warehouse operating costs. In warehouses with manual picking operations, pickers routing time often is the main determinant of the picking time. There many strategies for organizing order picking routes. One of the basic and is commonly used ones is S-shape strategy due to its practicality and ease of implementation. However, this strategy rarely is the optimal, but can be relatively easily adapted to the certain warehouse conditions. Thus, the paper presents a study on few systematic modifications of the classical S-shape strategy adjusted to the structure of aisles that can be found in different warehouses. Detailed assessment of the efficiency improvement of each proposed modification is provided.

Keywords: Order picking, s-shape, warehouse

1. INTRODUCTION

The organization of the order picking process has the greatest impact on the efficiency of a warehouse or a distribution center, and thus on efficiency of the whole supply chain. From the moment of accepting a customer order through its completion, to the moment of delivering a completed order to the customer, there are many possibilities for mistakes both in terms of accuracy and completeness, not to mention time waste [1]. Over the last decades, there have been many publications devoted to the examination of the order picking process. In addition, new problems have been identified, and new models have been developed. Nevertheless, there is still a gap between the industrial practice and research studies, because not all new methods developed for scientific research conditions can be directly applied to real industrial conditions. On the other hand, the existing industrial solutions do not follow current requirements and new, improved algorithms are often needed. The issue of order picking in man-to-item storage systems seems particularly important, which, despite the continuous growth of automation, accounts for the majority (about 80 %) of existing warehouses [1,2].

In the warehouses with a large assortment diversity (up to several dozen thousand storage units, so-called SKU - Stock Keeping Unit), it is first necessary to ensure the efficiency of the order picking process, i.e. the completion of customer orders. The basic factors influencing the effectiveness of this process are [2,3]:

- the arrangement of zones in the warehouse,
- the method of storage and distribution of products in the storage space,
- the way of picking items and organizing the routes from the storage zone to picking or shipping points,
- the way of managing incoming customer orders (grouping orders, prioritizing tasks, etc.).

Order picking efficiency (completion) can be improved by reducing picking time. The total picking time can be roughly divided into the time of driving or walking to storage locations, the time for picking up the items and the time of other activities (e.g. obtaining a completion list, preparing containers, etc.). In warehouses with manual picking operations, the driving time is often the largest component of the total picking time [2,3]. For this reason, it is reasonable to look for methods that will enable the preparation of order picking plans that will allow to minimize the total time needed for driving or walking to the storage locations. The publication list on the subject has a number of positions, in which the authors propose different solutions to the problem of routing in a warehouse. These approaches include various routing strategies, heuristics, metaheuristics and optimal solutions. In practice, optimal approaches to the routing problem are not often used, primarily because of their high computational complexity and because they tend not to take into account many real assumptions and constraints. In practice, several routing heuristics are used, and their performance usually depends on the specific parameters of the particular warehouse for which they are applied. The most commonly used routing algorithms known from research papers [2-4] are S-shape, return, midpoint, or largest gap heuristics. Although they are widely known, their application in real conditions often requires some adjustment.

As has already been pointed out, the problem of determining efficient routes for pickers is one of the factors determining warehouse efficiency [5]. The length of the route traveled by the pickers depends on the adopted routing method, but also on the size of the warehouse and the number of retrieved goods. In this study, the authors propose two modifications of the classical S-shape alignment heuristics and present the results of simulation experiments and the comparative studies of the proposed modifications with the original version of the S-shape algorithm.

The diagram of the magazine that will be used in the further part of the study is shown in **Figure 1**.

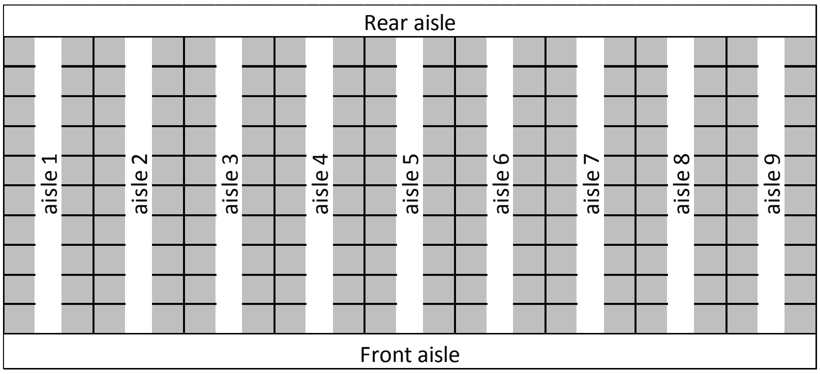

Figure 1 A structure of an exemplary warehouse.

2. S-SHAPE HEURISTIC

S-shape heuristic is one of the simplest and most common heuristics for order picking [6]. At the same time, the name of the heuristic reflects the principle of its operation: in order to complete the order, the worker moves along subsequent aisles containing any items to be taken, heading to the last aisle, always passing along the entire aisle he enters and then proceeding to the next aisle (containing the items to be taken). The shape of the road, which the worker is traveling, resembles the letter “S”. **Figures 2 and 3** show an example of the use of S-shape heuristic for picking ordered items (marked in black).

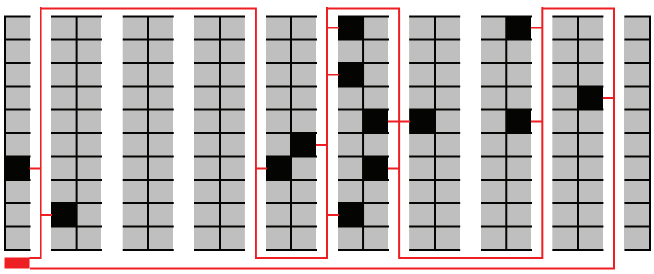

Figure 2 S-shape heuristic (1).

In the example shown in **Figure 2**, the place from which the picker starts is identical to the place where he delivers the completed order (marked with a red rectangle in the bottom left corner). The worker starts picking items for the order from the first aisle, where there are two items and he goes to the end of this aisle. Then, he omits two alleys where there are no items to pick and goes to the next aisle in which he collects one item. Continuing with the picking, the worker passes through successive aisles in which items for picking are located, omitting those aisles where such items do not exist. After passing the last aisle containing the ordered items, the picker is directed to the pick-up point of the complete order.

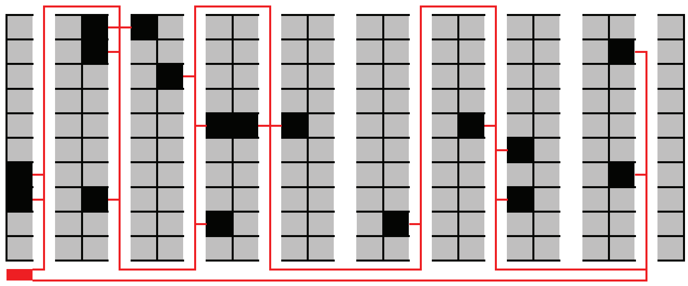

Figure 3 S-shape heuristic (2)

Figure 3 illustrates the situation in which a picker does not have to go to the end of the aisle from which he collects the item. Such a situation takes place only in the case of the last aisle (from which the items are to be collected), when the picking-up point is on the side where the picker enters the aisle (in this case - when the number of aisles containing the items to be picked is odd). The improvements of the S-shape heuristic presented further in this paper concern such a situation.

3. DESCRIPTION OF IMPROVEMENTS

In existing research, only a few examples of the improvements devoted to the S-Shape heuristic can be found. Dukic and Oulic [7] showed how a combination of different routing, storage and order batching methods could be used to save up to 80 % of routing distances in some specific cases. Moeller [8] showed, however, that in the specific case presented it was possible to build a routing algorithm and apply it, among others, to the S-Shape strategy, which shortened the routes the pickers had to travel by 7.4 %.

The improvements proposed in this paper relate to the S-Shape heuristic itself, in the case where the number of aisles from which items have to be collected is odd (this value is not identical to the number of aisle in the entire warehouse), assuming that the starting and ending points of picking are located in the same main corridor (on the same side of the warehouse).

Figure 4 shows an example of the arrangement of the items to be picked (for the warehouse structure presented in **Figure 1**).

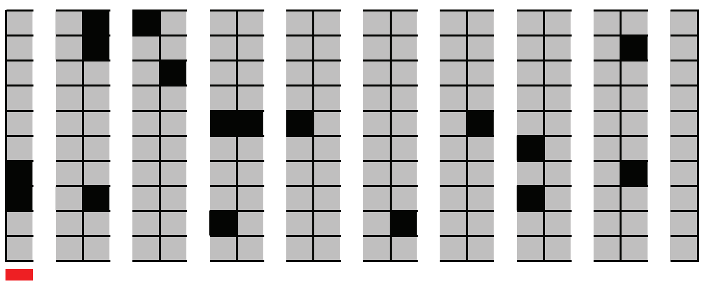

Figure 4 The warehouse with the items selected for picking

The route for the picker designated using the S-shape heuristic (for the example shown in **Figure 4**) is shown in **Figure 3**.

Due to the odd number of aisles from which the items are to be collected, in the last aisle the picker returns to the corridor leading to the pick-up point.

3.1. S-shape+ heuristic

The first of the proposed improvements is checking whether the turning back (which should be done due to the odd number of aisles) would not be more efficient in the first aisle instead of the last one. **Figure 5** shows the S-shape+ heuristic route.

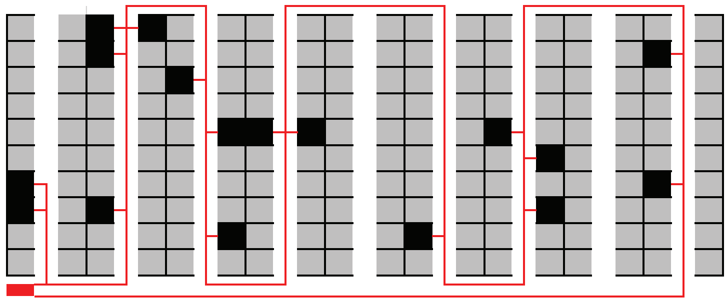

Figure 5 The picking route based on the S-shape+ heuristic

In the analyzed case, it is more beneficial (due to the length of the route covered) for the picker to turn in the first and not in the last aisle. By checking in which aisle it is better to make a turn, it is possible (in some cases) to shorten the route of the picker.

The S-shape+ heuristic allows for the shortening of the travelling distance, if the following conditions occur in the same time:

- the number of aisles from which items are taken is odd,
- the distance to the last (farthest) item in the first of the aisle visited is smaller than the distance of the farthest item in the last aisle.

The S-shape+ heuristic allows to get results which are not worse than the original S-shape heuristic.

3.2. S-shape++ heuristic

The second of the proposed improvements is checking whether turning back in any aisle other than the first or the last one (as called for by the odd number of aisles) would be more beneficial. **Figure 6** shows the operation of S-shape++ heuristic for an exemplary warehouse presented in **Figure 1**.

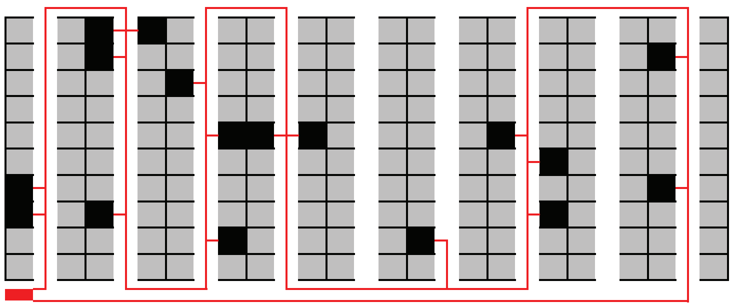

Figure 6 The picking route based on the S-shape++ heuristic

S-shape++ heuristic allows to get shorter routes of picking items than S-shape and S-shape+ heuristics, providing that:

- the number of aisles from which items are taken is odd,

- the location of the last (farthest) item in the aisle which is not located on the edge (from the aisles from which the items are to be collected) is smaller than in both aisles located on the edge.

It should be noted that the farthest commodity in the S-shape++ heuristics should be understood as:

- item as far as possible from the upper corridor for even aisles (counting only the aisles that the picker has to visit),
- item as far as possible from the lower corridor for the odd aisles.

In the example shown in **Figure 7**, a picker visits 7 aisles. The picker turns back in the aisle 5, because for this aisle, the farthest item is closest to the corridor - in this case, due to the odd value of the aforementioned aisle (5) - the lower corridor.

The results obtained using the S-shape++ heuristic are never worse than the results of the S-shape and S-shape+ heuristics.

4. EFFECTIVENESS STUDY OF THE IMPROVEMENTS

For the purpose of checking the effectiveness of the improvements of the S-shape heuristic described above, simulation tests have been carried out, in a warehouse with the following parameters:

- width of a single place on the rack: 1.2 meters
- width of the rack: 0.7 meters
- widths of the aisle: 0.75 meter.

The simulation has been carried out for a different number of items to be picked, as well as various warehouse parameters (the number and the length of aisles). For each of the analyzed numbers of items to be collected and the given warehouse parameters, 50,000 cases of random placement of items in the warehouse have been analyzed. **Table 1** presents the values indicating the percentage change in the average length of the picking route (compared to the length of the route determined by S-shape heuristic), as a result of the described improvements (S+ denotes S-shape+ heuristic and S++ denotes S-shape++ heuristic).

Table 1 Average change in the length of the picking route depending on the number of items

Number of racks	S+	S++	The number of places in the rack	S+	S++	Number of items	S+	S++
10	-2.89 %	-6.34 %	10	-0.83 %	-1.85 %	3	-6.47 %	-9.54 %
16	-2.19 %	-4.99 %	15	-1.30 %	-2.87 %	6	-2.67 %	-5.16 %
22	-2.04 %	-4.78 %	20	-1.75 %	-3.85 %	9	-2.27 %	-4.99 %
28	-1.87 %	-4.39 %	25	-2.18 %	-4.80 %	12	-1.97 %	-4.68 %
34	-1.73 %	-4.05 %	30	-2.59 %	-5.70 %	15	-1.76 %	-4.41 %
40	-1.61 %	-3.77 %	35	-2.99 %	-6.58 %	18	-1.57 %	-4.10 %
46	-3.10 %	-5.91 %	40	-3.39 %	-7.45 %	21	-1.42 %	-3.82 %
AVG	-2.20 %	-4.89 %	AVG	-2.15 %	-4.73 %	AVG	-2.59 %	-5.24 %

Based on the results presented above, it can be concluded that the S-shape++ heuristic allows to get the best average results. The biggest differences between the S-shape heuristic and the proposed improvement can be observed for a small number of items to be collected and a small number of long aisles.

In the simulation carried out for the purposes of the article, no limit has been introduced as to the number of aisles in which the items are located (for the proposed modifications to improve the results obtained by the S-shape heuristic this value must be odd). Therefore, in all cases the presented improvements had a chance to improve the route determined by the S-shape heuristic. Out of over 17,000,000 items analyzed in the warehouse, the S-shape+ heuristic allowed to obtain better results when compared to the S-shape heuristic in 26.9 % of analyzed cases. Improvement of the S-shape++ heuristic was observed 43.2 % of cases.

5. CONCLUSIONS

The proposed improvements to the S-shape heuristic are its development, while its primary principle remains unchanged - the method of order picking, and thus - the way the picker moves around the warehouse. Each improvement introduced allows to shorten the average route of order picking by 2.2 % for the S-shape+ improvement and 4.8 % for the S-shape++ improvement. Due to the minimal changes in the picker movement scheme introduced in the proposed improvements, the results obtained using S-shape+ and S-shape++ heuristics can be considered as a least satisfactory. The improvements presented above can be very low-cost to be implemented in the warehouses that use S-shape heuristic to designate picking routes.

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