Acta logistica - International Scientific Journal about Logistics
Volume: 10 2023 Issue: 1 Pages: 121-133 ISSN 1339-5629



*https://doi.org/10.22306/al.v10i1.367* *Received: 13 Jan. 2023; Revised: 14 Feb. 2023; Accepted: 28 Feb. 2023*

# Design and control order picking route of a retailer warehouse using simulation to increase labour productivity

**Moh'd Anwer AL-Shboul**
King Talal School of Business Technology, Business Administration Department, Princess Sumaya University for Technology, Khalil Al-Saket St, Amman, Jordan, m.shboul@psut.edu.jo

***Keywords:*** order picking control, routing, warehouse management.
***Abstract:*** The aim of this study is to find out the optimal path for the manual picking process used by warehouse operators to enhance the productivity of the manual picking system in the retail warehouse in Jordan using simulation Software. WMS Software was used to determine the different picking methods and the distance travelled in each path of the order-picking process to discover the optimal layout design for the warehouse. Several time studies were conducted using the stopwatch to determine the average picking time for each operator using those paths that were suggested by the simulation program to choose the same arrangement. Then, the average throughput was calculated for each operator for each routing method. The results showed that there is a strong correlation and relationship between the routing method and operator productivity. Further, it is found that productivity is higher by 29% when the operator chooses the optimal path shown by the simulation program, and this improvement in order picking will lead to a high level of service satisfaction and a lower level of operational cost for storage. Improving picking methods and optimizing picking paths can increase the total number of orders an operator can fulfil in a single working day, resulting in increased operator utilization.

## 1 Introduction

Warehouses are the link between production points (such as factories and the like) and various sources of consumption in the supply chain (SC), so the work of warehouses is considered important and necessary in different SCs [1]. In this study, we use one way to reduce the handling time by finding the optimal routing design of the warehouse. Most retail warehouses have difficulty defining the accurate workforce, because the workload is highly variable and volatile, particularly the outbound businesses that have strict commitments. The storage process is directly related to other logistical operations such as transportation, care, picking, handling, loading, unloading, packaging, processing and repair and maintenance operations for goods and products between different production points and consumption points in different markets and countries [2]. There are several different operations and activities that take place inside warehouses, such as receiving orders, locating storage, replenishing the shortage of products, preparing and processing different orders, accumulating and sorting goods, packaging, and distribution, sending orders and shipping them within their specified time.

The order-picking process is a retrieving logistical activity of different products from particular storage zones according to customer orders. Generally, one of the logistical activities inside warehouses that consumes a long time is the processes of selecting and picking different orders, as it contributes significantly to raising the total storage costs. [3] indicated in their study that 70% of the time it takes to pick the order, while it includes 55% of the total storage costs. The order-picking logistical task could be multi-dimensional (i.e. one, two, and up to three). Order picking productivity can be enhanced by minimizing the time of handling. The factor of picking time can be divided into the time required to reach the product storage location (walking and access time). In addition to the time of other remaining logistical activities such as the time of product selection and picking the products (obtaining a pick list and an empty pick holder) through manual selection processes inside warehouses, and often it is considered time access to the product is the largest factor in the total time at the time of picking [4]. To decrease the tour time to pick up the order, various methods can be used through more efficient control mechanisms. Zoning is one of the method that used to minimize the travel times, that is an order picker picks just that part of an order, which is in his or her assigned zone. Other method is the storage task rules that can decrease tour times by allocating goods to the correct storage positions. For instance, repeatedly demanded goods can be stored where they are readily to be accessed. Another approach is to accumulating/assorting as a means of minimizing tour times. Accumulating/assorting is interested in collecting different orders in a one-order-picking track (i.e. partially). The last method is to define good routes for order picking. The process of sequencing and finding the products required retrieving them from their storage places and positions must take into account the distance travelled to reach them. It is desirable that it be known and as short as possible, and this in itself is a problem in determining the paths and methods of selecting and picking orders, hence this study, which will present performance comparisons between optimum routing and inference on repositories [5].

This study was conducted in aim of performing five different manual routing maps created by the simulator for different methods including: S- shape combined, aisle-by-aisle, large gap in addition to a self–experimental rout done by a picker by walking through the warehouse to pick items as well as an optimal one in the retail warehouses in Jordan. The performance of all those routes is compared to identify the best and optimal order-picking route for the same order with the highest picker's productivity in the warehouse; that generates the shortest order picking routes. The S-shape routing policy or the traversal strategy that each sub aisle including at least one requested item leads to a path that is traversed totally. These path aisles are travelled in an S-shape form [6]. It is the simplest strategies for routeing pickers he or she gets in an aisle from one end and leaves from the other end, starting at the left side of the warehouse. In the picker returns to the front end of the aisle after picking the last item. Routing strategy is used when the further time to modify lanes/aisle is terse and the quantity of picks per aisle is few. The idea was presented as an aisle-by-aisle route by [7] which refers to the route that the order picker visiting each pick aisle only once. In this strategy, the tour will start from the left side of the corridor/aisle that exist in the warehouse containing the items, the items in that main corridor/aisle are selected and a cross corridor/aisle is chosen to move forward to the next main corridor/aisle. Therefore, this route specifies the intersecting lanes/cross-aisles that must be used and walked in them from one corridor/aisle to another in a sequential manner so as to reduce the distances traveled to select the request. Minor changes have been made to this adopted path since these paths start and end at the warehouse and that because this rout compatible with the other routing strategies [8]. The combine or hybrid routing method combines and merges the best attributes of the return and cross-cut methods. The composite strategy minimizes the journey distance between the extreme picks in two closest aisles [9]. This route will be started and ended by a picker at the warehouse. Then picker moves through the leftmost pick aisle that consists of goods across the block outmost from the warehouse that has goods. Consecutively, the sub-aisles of the furthest bay/zone are visited from the left-hand side to the right-hand side. After that, the picker gets into the next block/bay; the one block/bay that is nearest to the warehouse. Then picking the items in this bay/block. Then again until all bays/blocks with items have been visited. The sub-aisles are either totally traversed or the order picker enters and/or leaves the sub-aisles from the same flank [10]. Optimal routing method is calculated the shortest order picking routes in warehouses, regardless the design or storage places/positions of the items. The best (short)/optimal routes seem like a blend of S-Shape and the largest gap. The majority of order picking processes use heuristic routing methods. This strategy is commonly used in practice since it simple to know more and produce routes that are quite consistent in nature [11].

Therefore, this study sheds light on the analysis of the process of picking orders in retail warehouses in Jordan to reach the solutions and recommendations that are necessary to solve the problems related to this important process, where the rest of the parts of this study are included the following sections. Section 2 is a background literature review that is highlighting warehousing and order-picking operations and optimization, in addition to the warehouse's internal layout and routing tracks and extensions of some current routing methods. Section 3 contains the purpose and the study questions. In Section 4, the simulation model is described to compare the performance of all routing methods. Section 5 illustrates the results and discussion. The conclusions of this study are available on section 5. Finally, section 6 includes limitations of the study and future works.

## 2 Literature review

### *2.1 Warehousing and order picking systems optimization*

Warehouses are considered a safe place to receive goods and products in large quantities. Warehouses provide the necessary environment to maintain them in a safe and secure manner and for varying periods of time, then work on preparing and rearranging them according to customers' requests to send them in smaller quantities and in different places. This is knowing that warehouse operations contain inbound logistical processes (i.e. receiving, and storing goods, etc.) and outbound logistical operations (.e. order picking, packing, distribution, etc.). While warehouses frequently control the smooth flow of products in a good manner due to restricted linkages with their providers/suppliers, many prior studies concentrated on either outbound or inventory logistical processes [12]. Usually, most of their customers work in a timely manner (i.e., just in time) and have an urgent need to receive their orders and deliver them within a period short time. While inbound warehouse operations minimum time tension is exercised as arriving products are stocked as safe stock without the use of few unit load handling [13], except for cross-docking products. In addition, warehouses have the ability to adjust their workforce within the warehouse to speed up the preparation of various orders for their customers due to fluctuations in demand, which facilitates accurate forecasting of the volume of short-term work and effective labour management necessary for chain operations as a whole. In addition to identifying and choosing appropriate locations for storing goods in order to speed up the various picking operations and optimizing routes and time [14].

The picking of orders is considered one of the most important operations within warehouses, which require time and cost in preparing customer orders, for this reason it requires the provision of a large human factor in order to reduce the time required for the picking process as much as possible and to the minimum [15]. Therefore, the process of picking orders is considered one of the processes that require more labour-intensive operations inside warehouses, especially those warehouses that still use manual systems in the picking order process, which increases the operational cost of the entire supply chain. As for warehouses that use modern and automated systems. They require labour less, faster, and less time, which increases the level of service in a satisfactory manner. Knowing that most of the previous studies indicated in their results that the picking order process is estimated at more than 50% of the total operating expenses of warehouses. As a result of that competitive models for cost reduction help the professionals of warehousing to take into account the order-picking logistical activity, which is considered the highest factor portion to improving the productivity [16]. Most of the previous studies indicated and focused on the importance of picking orders and including them in one of the four operating strategies in order to improve the performance of the system through proper and effective planning of material flow, picking orders in a sequential manner, effective routing, as well as choosing suitable and more effective storage places. In addition, the policy of the process of picking orders includes designating the appropriate elements for handling the materials, and determining the locations of the orders, and the best paths for the rounds of picking through a number of effective functions. Additionally, including them in the system such as collecting, sorting, batching, classifying, and dividing areas/zones in a way that suits the nature of the stored materials. Where, paths are identified and directed to pick different orders in several ways, ranging from simple heuristics to the optimal path and procedures. It is necessary to estimate and specify the SKUs for each product in its storage locations. In general, the most widely used and common warehousing operations are random warehousing, which depends on the basis of category warehousing, so that goods are sorted on the basis of ABC analysis across different warehousing categories. Therefore, proper and organized planning processes based on a scientific and thoughtful basis play an important role in choosing the efficiency that involves guidance, the selection site, and the identification of cross paths and paths [17]. Increasing the service level of productivity with respecting resource constraints is the most popular aim of order-picking operations. The ultimate important connection between the order-picking operation and the level of service required is that the acceleration the picking is done will become better. Travel of journeys is performed around 50% of the time required for the order-picker process in an ideal picker-to-parts warehouse. Therefore, it is a most committed issue for improvement. [18] presented an optimized journey time or journey distance in short time and way in the warehouse. Thus, the manual picking order processes that the person can concentrate on the typical internal warehouse layout design, stock activity approaches, routing approaches, demand batching, order sorting and allocation, and zoning as shown in (Figure 1). [19] presented that six policies that were mentioned previously, if they are improved, ensure that warehouse work remains within the tactical and operational levels alike, and this procedure is necessary and important for warehouses whose decisions are based on a strategic basis and are not easy and expensive for alert purposes. The warehouse's internal layout design regards the defining the number of blocks, in addition to the aisles' length and range in each block. Therefore, the primary goal is to reach the best layout, and approach for warehouses. In relation to certain functions, taking into account the main requirements, restrictions, regulations, and security and protection instructions for both personnel and products. With a great focus on the important, sensitive, and most common function, which is determining and calculating the distance and time of arrival to the goods to be reached quickly and in the least time [20]. It is possible to follow the scenario of zoning within the warehouses, where the order-picking zone can be split into various other areas/zones, each area/zone for which a certain operator is allocated so that he chooses the part of the order within the area/zone allocated to him/her. Therefore, one of the main advantages of zoning is that each picker is limited to a specific area only, which works to reduce traffic congestion and allows the picker to identify the main contents of the goods within his/her designated area/zone. However, this scenario is represented by a major disadvantage, which is the division of orders, which often works to merge orders with each other before the process of transferring and shipping them directly to the customer. As for the order batches, it works to set specific groups of orders into a certain number of sub-orders, after which every group can be picked during one round of picking. Two factors for this batching process are the nearness of the picking sites and the time. [21] defined the accumulation/sorting (A/S) process as the collecting meet the items per customer order by applying the batching and/or zoning with some further efforts. The aim of the work presented in this case study was to find out the best approach for improving the overall productivity of the picking orders process in the warehouses (select the best routing method). To achieve this aim, a method was enhanced to estimate the productivity of the manual order picking, taken into consideration various options, in a total of five options (including 5 routing methods in addition to self-experimental case), respectively after the implementation of various routing methods. By applying and created, a simulation model in this study, the picking time was considered for measuring of the performance. A variety of alternative routing methods was tested.

### *2.2 Labour productivity*

In retail distribution warehouse the customer demand is usually customer orders are characterized by short-term fluctuations. In a number of recent studies that were applied to warehouses, it indicated in its results that warehouses in general resort to hiring permanent employees and temporary workers in order to keep pace with the change in requests and adapt to the fluctuations that may occur at workload [22]. Some warehouses deliberately work to their full capacity and staff from permanent employment in only one case if they cannot depend on tentative employment obtainable at the appropriate one. This study presents that the enhancement of the labour productivity by using the optimal routing method could help the decision makers to organize and manage the number of workers in warehouses, which is a vital and important issue, it is necessary to deal with and keep up with fluctuations in daily customer request**.**

### *2.3 Warehouse layout design and routing methods*

In this study the warehouse layout 's sketch has parallel of pick aisles and has no unused space as shown in (Figure 2).The warehouse layout consists of two blocks, in which every block has a number of sub aisles. Whereas inside each block a sub aisle is part of a pick aisle. The aisle' can be used when a statement holds for both aisles including the pick and sub-aisles. Cross aisle exists at the back and front of the warehouse and in the mid site of every pair of blocks. In spite that cross, aisles do not have storage locations and do not contain items, through which it is possible to work on the use of aisles. Each block contains a corridor that connects the front façade with the rear of the storage area, as the rear façade of one of the rear blocks serves as the front aisle for the block that is located in the front façade excluding the first block. Therefore, the number of intersecting aisles inside the warehouse is the number of blocks adding one, due to the presence of one cross aisle in the front and another in the back, in addition to the presence of other passage between every two blocks adjacent to each other [23]. The operators of the order picking are supposed to be able to pass and cut aisles in both directions and also be able to alter direction inside the aisles as well.

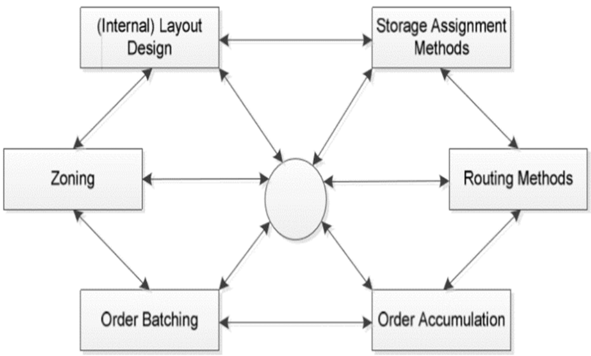



*Figure1 Improving low-level, non-automated order-picking tasks [14]*

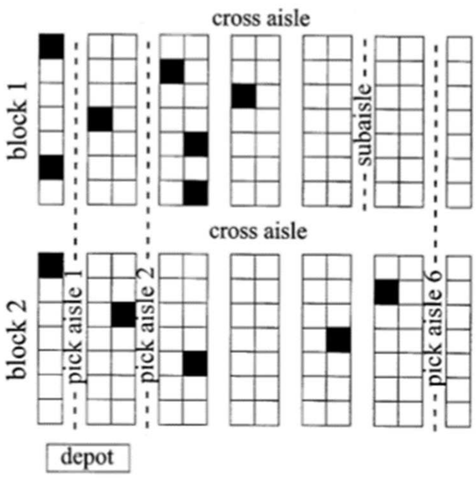



*Figure 2 The warehouse layout with multiple cross aisles*

[24] show that the aisles are narrow enough to allow picking from both sides of the aisle without changing position. Each order consists of a number of items that are usually spread out over a number of subaisles. Where the warehouse is located at the beginning of the first asiler of the first interface, and also note that the location of the warehouse can have a major role on the mean joureny time. Routing policy is a policy to determine the rout inside the warehouse. The term rout refers to the path that go over an order of all of the item. Routing strategy linked with ordering a pick list in an organized order that will reduce the travel distance of the order picking [25] showed that the aim of routing techniques is to put the products in sequence on the pick schedule to produce a proper route over the warehouse. Practically, the problems of the order pickers routing in a warehouse is almost resolved using heuristics [26] mentioned in their study, that number of empirical and practical methods were distinguished for routing the order pickers in the depots. However, they were carry out the single-block storage process, with presenting a number of methods such as traversal in the form of the letter S, the midpoint, return, the large gap method, and the aggregate method (compound). This study describes below different types of routing: S-shape and largest gap, both of these two route are a well-known rout for basic layout. Moreover, aisle by-aisle route, which is the routing method of [27]. The fourth one is the combined rout; it is a combined strategy (hybrid) that accumulating parts from S-shape and largest gap. In addition, the optimal rout for finding the route of the shortest travel distance.

#### 2.3.1 S-shape

The S-shape routing technique is also called the traversal strategy that every aisle containing at least one requested item leads to a path is traversed totally. It is the simplest strategies for routing pickers this route is where an order picker gets in from the edge of the aisle, while departing from the end of the other edge, starting from the left side of the depot. Aisles and sub-aisles are bypassed and skipped, when there is no process to pick anything up any order. Therefore, in this route, the main aisles are passed in the form of the letter S. The picker returns to the front end of the aisle after picking the last item. This rout is used usually, since it is very easy and simple to apply it. However, it outperformed by more complex heuristics. [28] in their study, they mentioned that this strategy works to enhance the time and distance of the round, because it can lead to the picker making rounds in other sub-regions/aisles in the cluster regions from left to right. Therefore, the picker has to traverse a large portion of the forward choppy lane (cross aisle) before he can return to the beginning of the warehouse. The function of the time-complication of this route is distinct from the number of pick positions and enhances linearly with the number of picking aisles. Sub-aisle has in basic not less than one pick location traversed over the whole length. In addition, as [29] showed, where the pick-up process performed by the picker starts from the front of the warehouse and takes place for proceeding ahead, then starting from the main aisles closest to the front façade of the warehouse, which contains at least one item and more. The process will be as in the following steps: (1) the main aisle of the warehouse is crossed to include the farthest block, which contains one item or more. (2) In the current block that contains only one element or more, the picker will immediately go to the left aside that contains more elements, or it will go to the right aisle, which also contains other elements, so that it will be the closest one in this case. (3) After that, the picker will pass from one aisle to another aisle, so that it traverses the aside containing the elements completely, then the picker will return to the beginning of the block (4). In case the block that has no elements, the aisle of that block is traversed, as this process will be repeated for all blocks until reach the block that is closest to the warehouse is reached (5). Lastly, the order picker goes back to the depot. See (Figure 3).

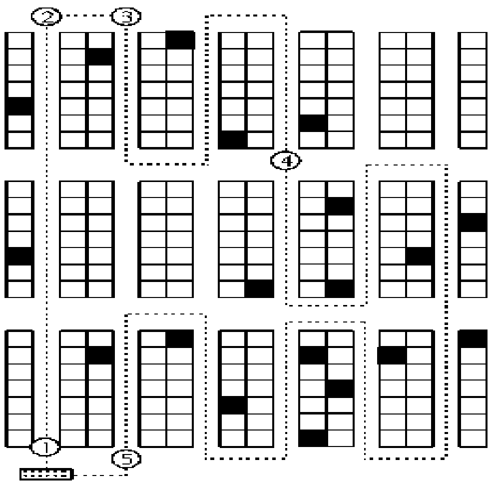


*Figure 3 S-shaped route-routing order pickers in a warehouse*

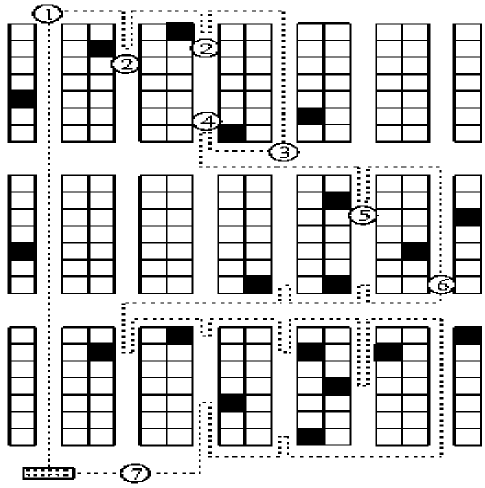


*Figure 4 Largest gap heuristic-routing order pickers in a warehouse*

### 2.3.2 Largest gap route

This strategy occurs when the order picker enters the aisle further into the gap of that aisle as well as all of the aisle's sub-aisles. This gap works to separate any two picks that are closely close to each other, meaning the first pick and the first pass picker, or the amidst of the last pick and the back aisle. Where this route is divided in the picking areas into two main groups through the sub-aisle, where one group is dealt with and entered in these locations through the use of the crossed back aisle, while the other groups are entered through the front cross aisle. In the block that one of the two groups is empty or even both, it is not important to enter the sub-aisle from this side. The largest gap inside an aisle is the order picker does not traverse the portion in that. When there are a largest gap between two picks which adjacent to each other, the picker chooses the route back by using both ends of the aisle. Moreover, a return route from the front or back aisle is used. The back aisle can just be accessed through the first or last aisle. This routing strategy used in the case that the extra time is short to change aisles, the amount of shots each aisle is also small. [30] showed that this rout usually outperforms the midpoint approach and the S-shape when the pick density is less than about four picks in each aisle. While, from an application viewpoint, the midpoint approach is easier and more direct. As shown in (Figure 4) in which the largest gap rout is used to pick items, like the S-shape route, the picker advances to the front of the nearest aisle in the warehouse that contains one or more items. Therefore, the aisle that contains the element is almost from the right or left side, since this aisle is completely traversed. Then, each aisle is entered at the posterior end of the depot until the "largest gap" and left from the same side in which it was inserted. After that, progress is made through the last aisle forward, and then the aisles that are located at the front end of the warehouse are entered into the "largest gap", which leads to the existence of another gap between each two adjacent picking sites, either within the sub-aisle or between a cross aisle and the nearest picking site. If all items to be prepared have been picked up, the picker returns to the warehouse.

### 2.3.3 Aisle-by-aisle rout

[31] presented this rout in which order picking routes visits each main pick aisle will just once. Where the first round of pickers in the warehouse begins by entering first from the far left side of the aisle that contains the items, and then the process of picking and selecting all the required items in this main aisle takes place, after that to move forward to the next main aisle, the cross aisle is chosen. Where this process will be repeated until all the required items in the main aisle are picked up, in addition to that, the work of the pickers continues in the next main aisle. Where the paths of the cross aisles that must be toured are determined and used to move from one lane to another in a way that reduces the distances travelled for the picking process. Some minor modifications are made in this tour because these tours start and end at the warehouse, and because the aisle is sometimes compatible with other routing strategies. See (Figure 5).

### 2.3.4 Combined (hybrid) rout

[32] presented the composite routeing method. This rout combines and merges the best attributes of the back and transversal methods. The composite strategy decreases the journey distance between the outermost picks in both adjacent aisles. [33] state that the aisles with picks in this rout are either entirely traversed or entered and left at the same end. In addition, it was indicated in their study that one of its main advantages is that it is distinguished and superior to other experimental methods/heuristics in numerous cases.

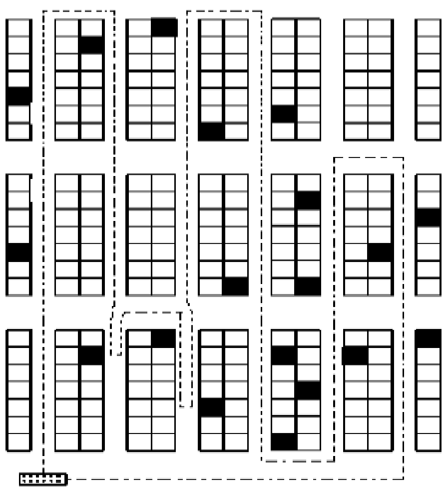


*Figure 5 Aisle–by aisle routing order pickers in the depot*

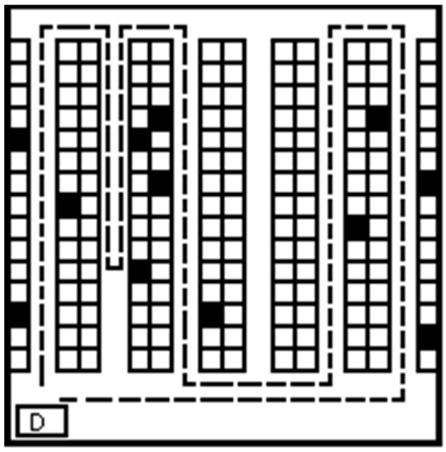



*Figure 6 Combined route-routing strategies*


*Figure 7 Research model of this*

Furthermore, [34] in their study, a comparative study was conducted of 80 cases in different warehouses for six methods of routing to report the combined heuristic, which was referred to in the results of the study on 74 cases out of 80 that they studied and analysed. Combined's drawbacks that being dynamic, the order picker is not allowed to recognize the routing heuristics. Furthermore, [35] developed a strategy in each case in which all the elements of one aisle are picked, an inquiry arises about going to the back end of the aisle or returning to the front end of the aisle. By making comparison of these, both choices with each other to know which substantial will produce the shortest route. Therefore, there are always two routes that are possible to follow. See (Figure 6).

From a practical point of view, there was a need to highlight and use a routing strategy that generates clear and simple pathways to understand its structure. There are different patterns of clear routes, which work to reduce the time required to pick the product by the picker in finding and specifying storage locations for different materials, as well as working to reduce the risks of errors that may occur during the selection/picking process. Therefore, the mixed/hybrid routing method may result in such kind of use of these routes. Order picking routes visits each sub aisle that contains items just once. This rout will be started and ended by picker at the warehouse. After that, the picker goes along out of the pick aisle, usually from the left side, which consists of several items, towards the block farthest from the side of the warehouse, which contains the items needed to be picked. Consecutively, the process of visiting the next aisles branching from the main aisle (sub-aisle) to the farthest block from the left to the right, after that, the

Acta logistica - International Scientific Journal about Logistics
Volume: 10 2023 Issue: 1 Pages: 121-133 ISSN 1339-5629


picker enters the logical block of the next block. Which is considered the one block and is the closest to the warehouse, and then the picker selects the elements to be selected/picked in this block. Then this process is repeated until all the blocks that contain the elements to be accessed are visited, picked and prepared, where the sub-aisles are completely crossed or the order picker enters and leaves the sub-aisle from the same side [36].

#### 2.3.3 Optimal routing method

An optimal routing developed by [37] to route warehouse operators to walk in a rectangular manner in the warehouse without cross aisles. Regardless the design or storage location of the items, this strategy is calculated the shortest order picking routes in warehouses. Optimal routes seem like a mixture of S-Shape and Largest Gap. The majority of order picking processes use heuristic routing methods. This strategy is commonly used in practice since it simple to know, produce and understand the consistent pathways/routes in nature.

## 3 Purpose of the study and research question

This study aims to find out the correlation between the productivity of the operator with the different routing methods used in the picking process. Moreover, it answers the question of how the rout layout of the manual picking process effect operator productivity in the warehouse.
The research model of the study presented following scheme as illustrated in (Figure 7).

## 4 Research methodology

### *4.1 Research design*

This study mainly follows a simulator software. The first research question is about the optimal layout design of the warehouse routing, and its role in improving the productivity of the manual order picking system. While, the second one is about its benefits in reducing the overall cost in warehouse sector which aimed to describe strategies applied by decision makers to make recommendations for the company through knowing the optimal routes. In this study, various sources of data have been used, including: EHS website, videos, company documents, textbooks, scientific journal articles, internet sources, newspaper articles, as well as documents.

### *4.2 Methodology*

The warehouse studied in this research is a low-level picker to stock manual order picking system. The warehouse layout structure composed of 2 blocks as shown in (Figure 8) each block consists of 6 wide aisles and each aisle have of 11 picking locations, the aisles are open from both side such that allow the operator to move within the aisle in both directions. The depot is located at the bottom left corner of the first aisle, order-picking start from the depot where the operator fined the order list and the cart. For this case study, an interactive warehouse simulator, time study and excel was done.

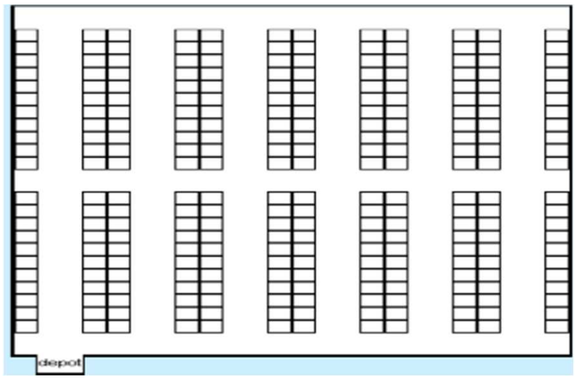


*Figure 8 Warehouse layout and depot location/top view (Developed by authors)*

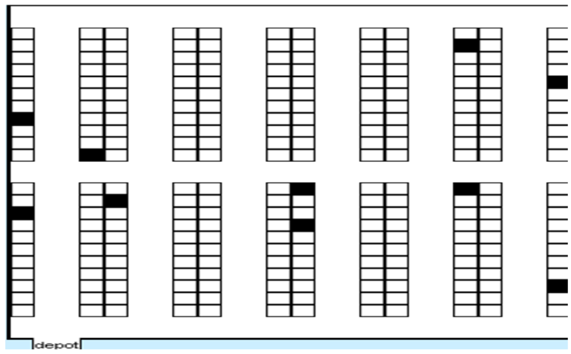


*Figure 9 Order distribution-top view of storage area storage area (Developed by authors)*

### *4.3 The interactive warehouse*

The simulator was used to determine order picking routes map and the average travelled distance in each rout for the same order distribution, a top view of the warehouse created by the simulator after defending the parameters (number of blocks, number of aisles, number of locations per aisle, depot location, aisle length, crossover length). Each square depicts a storage location. Walking is possible in the aisles between the black squares. The simulator creates a map for five different routing including the optimal one using different methods, which are: (1) S-shape; (2) Combined; (3) Aisle by aisle; (4) Largest gap; (5) Optimal; and (6) Self-experimental. One of the operators was asked to generate his own route (self-experimental), without using any of the routing methods, using the simulator. The simulator calculated the total travelled distance in meter for each route.

### *4.4 Time study analysis*

This study was made to determine the average picking time that the operator needs to complete each route, a stopwatch was used. Picking time *Tp* is calculated using equation (1) as shown below [38]:

$$Tp=t1+t2+t3+t4 \quad (1)$$

*Where:*
*t1 –Average travelling time [s]; t2 –Average extracting and searching time [s]:*
*t2=x1·x2· ti (x1– Average number of locations per Order [pieces], x2– Average number of positions Per location [pieces], t3 –Information Processing Time [s]: t3= (10–15 s)·x1; ti– Time needed for picking. On one position (3-6) [s]).*

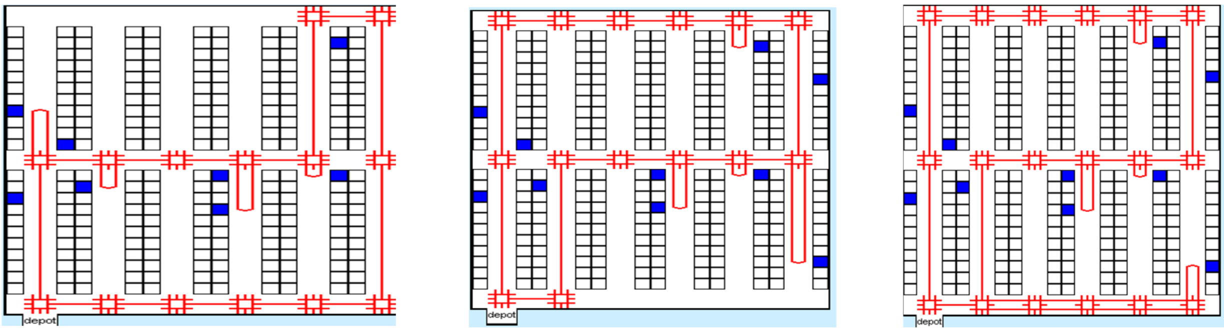
Five operators did the experiment and they were followed in order to define the total picking time they need to complete each rout. The operator starts from the depot with the map of each rout and he asked to pike the given order using the given route map. For each route, an average picking time was taken. Since the operator work 7 hours/day the productivity of the operator (how many orders the operator can accomplish in each working day) was calculated for each route to define the effect of routing method on labour productivity.

## 5 Results and discussion

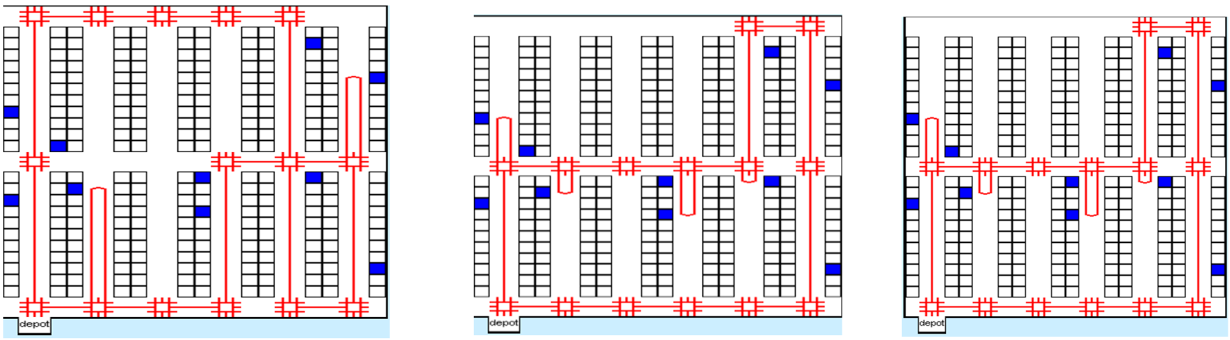
In this section, the experiment result will be presented to help in understanding the used methodology.

### *5.1 Interactive warehouse simulation*

In this part the simulator generates a random order as shown in (Figure 9), then a map for each routing methods created by the simulator as shown in (Figure 10). The simulator calculated total travelled distance for each route A time study was performed to determine the speed for the five operators using stopwatch after that the 5 operators were asked to pike the order using the given route and the picking time was measured using Equation 1, the result for each route each route shown in following Tables.



*A. Aisle by aisle route map* *B. Combined route map* *C. Largest gap*



*D. S-shape route map* *E. Self-experimental route map* *F. Optimal route map*

*Figure 10 Routes Map-Top View of Storage Area*

*Table 1 S-shape route total picking time*

S-Shape Route 320.09 Meter

| Operator | Speed (m/s) | T1 (sec) | Time Needed for Picking on One Position | T2 (sec) | Processing Time Per Location | T3(s) | T4 (s) | Picking Time(s) |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.83 | 385.65 | 5.00 | 50 | 12.5 | 125 | 230 | 790.65 |
| 2 | 1.23 | 260.24 | 3.00 | 30 | 10 | 100 | 200 | 590.24 |
| 3 | 0.87 | 367.92 | 5.00 | 50 | 12 | 120 | 250 | 787.92 |
| 4 | 0.76 | 421.17 | 6.00 | 60 | 15 | 150 | 280 | 911.17 |
| 5 | 0.9 | 355.66 | 4.00 | 40 | 11 | 110 | 200 | 705.66 |
| Average | | 358.13 | | | | | | 757.13 |

*Table 2 Combined route total picking time*

| Combined | 244.45 | Meter | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Operator | Speed (m/s) | T1 (sec) | Time Needed For Picking On One Position | T2 (sec) | Processing Time Per Location | T3 (sec) | T4 (sec) | Picking Time(s) |
| 1 | 0.83 | 294.52 | 5.00 | 50 | 12.5 | 125 | 230 | 699.52 |
| 2 | 1.23 | 198.74 | 3.00 | 30 | 10 | 100 | 200 | 528.74 |
| 3 | 0.87 | 280.98 | 5.00 | 50 | 12 | 120 | 250 | 700.98 |
| 4 | 0.76 | 321.64 | 6.00 | 60 | 15 | 150 | 280 | 811.64 |
| 5 | 0.9 | 271.61 | 4.00 | 40 | 11 | 110 | 200 | 621.61 |
| Average | | 273.50 | | | | | | 672.50 |

*Table 3 Largest gap routing total picking time*

| Largest Gap | 237.55 | Meter | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Operator | Speed (m/s) | T1 (sec) | Time Needed For Picking On One Position | T2 (sec) | Processing Time Per Location | T3 (sec) | T4 (sec) | Picking Time(s) |
| 1 | 0.83 | 286.20 | 5.00 | 50 | 12.5 | 125 | 230 | 691.20 |
| 2 | 1.23 | 193.13 | 3.00 | 30 | 10 | 100 | 200 | 523.13 |
| 3 | 0.87 | 273.05 | 5.00 | 50 | 12 | 120 | 250 | 693.05 |
| 4 | 0.76 | 312.57 | 6.00 | 60 | 15 | 150 | 280 | 802.57 |
| 5 | 0.9 | 263.94 | 4.00 | 40 | 11 | 110 | 200 | 613.94 |
| Average | | 265.78 | | | | | | 664.78 |

*Table 4 Aisle-by-aisle route total picking time*

| Aisle By Aisle | 215.36 | Meter | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Operator | Speed (m/s) | T1 (sec) | Time Needed For Picking On One Position | T2 (sec) | Processing Time Per Location | T3 (sec) | T4 (sec) | Picking Time(s) |
| 1 | 0.83 | 259.47 | 5.00 | 50 | 12.5 | 125 | 230 | 664.47 |
| 2 | 1.23 | 175.09 | 3.00 | 30 | 10 | 100 | 200 | 505.09 |
| 3 | 0.87 | 247.54 | 5.00 | 50 | 12 | 120 | 250 | 667.54 |
| 4 | 0.76 | 283.37 | 6.00 | 60 | 15 | 150 | 280 | 773.37 |
| 5 | 0.9 | 239.29 | 4.00 | 40 | 11 | 110 | 200 | 589.29 |
| Average | | 240.95 | | | | | | 639.95 |

*Table 5 Self-experimental route total picking time*

| Self-Experimental | 380 | Meter | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Operator | Speed (m/s) | T1 (sec) | Time Needed For Picking On One Position | T2 (sec) | Processing Time Per Location | T3 (sec) | T4 (sec) | Picking Time(s) |
| 1 | 0.83 | 457.83 | 5.00 | 50 | 12.5 | 125 | 230 | 862.83 |
| 2 | 1.23 | 308.94 | 3.00 | 30 | 10 | 100 | 200 | 638.94 |
| 3 | 0.87 | 436.78 | 5.00 | 50 | 12 | 120 | 250 | 856.78 |
| 4 | 0.76 | 500.00 | 6.00 | 60 | 15 | 150 | 280 | 990.00 |
| 5 | 0.9 | 422.22 | 4.00 | 40 | 11 | 110 | 200 | 772.22 |
| Average | | 425.16 | | | | | | 824.16 |

*Table 6 Optimal route total picking time*

| Optimal | 215.36 | Meter | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Operator | Speed (m/s) | T1 (sec) | Time Needed For Picking On One Position | T2 (sec) | Processing Time Per Location | T3 (sec) | T4 (sec) | Picking Time(s) |
| 1 | 0.83 | 259.47 | 5.00 | 50 | 12.5 | 125 | 230 | 664.47 |
| 2 | 1.23 | 175.09 | 3.00 | 30 | 10 | 100 | 200 | 505.09 |
| 3 | 0.87 | 247.54 | 5.00 | 50 | 12 | 120 | 250 | 667.54 |
| 4 | 0.76 | 283.37 | 6.00 | 60 | 15 | 150 | 280 | 773.37 |
| 5 | 0.9 | 239.29 | 4.00 | 40 | 11 | 110 | 200 | 589.29 |
| Average | | 240.95 | | | | | | 639.95 |

The average Picking time for each route was calculated as shown in the above Tables 1, 2, 3, 4 and 5, then the productivity, how many order that the operator can perform in one working day, was calculated as shown in Table 6 for the operator when he use each route using equation 2:

Total working hours = 7 hrs/day
Productivity = total working time (min)/ total picking time needs to complete one order (2).

*Table 7 Productivity for each rout*

| Route | Average Picking Time (hrs.) | Productivity (Order/Person/Day |
|---|---|---|
| S-Shape | 320.09 | 33 |
| Combined | 244.45 | 37 |
| Largest gap | 237.55 | 38 |
| Aisle by aisle | 215.36 | 39 |
| Self-Experimental | 380.00 | 31 |
| Optimal | 215.36 | 39 |

As shown in (Figure 11), a strong correlation was found between the average travelled distance for each route and the operator productivity.

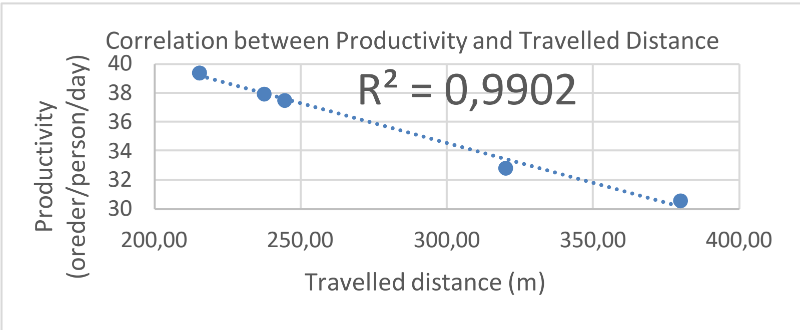



*Figure 11 Correlation between productivity and travelled distance*

As a result, the routing method the operator use can affect his productivity as shown in (Figure 12).

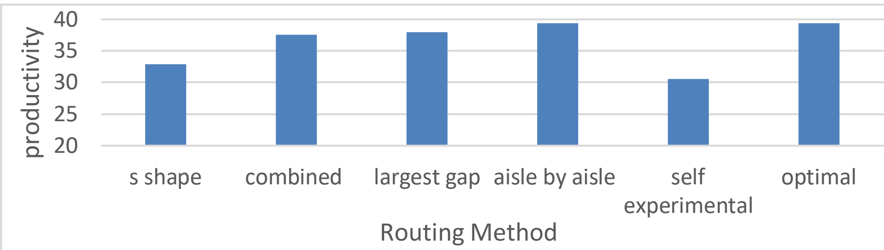



*Figure 12 Productivity for each routing method*

## 6 Conclusion

The main aim of this study work was to solve a relevant problem within the field of the logistics sector in general warehouses order picking route activity in particular, showing its influence on labour productivity and its contribution to the retailer warehouse in an emerging economy. Analysing and diagnosis of the current situation of the retailer warehouse order picking route was presented as the main problem the low productivity rate in the processes of storage and picking, resulting in the use of overtime to not affect the level of service to the customer-impacting on the cost overrun. The logistical activity of picking orders is one of the most important activities that depend on time in most warehouses, and that plays a big role in influencing the entire supply chain. From this point of view, this study provides suitable solutions optimize the route selected for order picking and preparation of different orders for customers in a rectangular warehouse that contains multi parallel-aisle with section aisles in the centre and edge of each aisle. Where this study aims to propose a directive policy that works to reduce the total time and/or shorten the distance travelled in the processes of picking and selecting different requests, which would reduce the total costs and work to raise the productivity of the labour available in the warehouse. Where this was achieved through the improvement in labour productivity using the simulation method. Two different ways/options adopted based on the order-picking process allocation into the warehouse have conducted the simulation. 12 various pick-order locations were simulated and the simulation delivered routes for various routing policies: S-shape, combined, largest gap, aisle-by-aisle, and self-experimental for both scenarios. The results illustrate that the proposed approaches outperform the S-shape, combined, largest gap, aisle-by-aisle, and self-experimental methods by 29%, 24%, 21%, 19 %, and 17%, respectively. The major outcome that can be reached from this conducted study, and based on the obtained results, is that the order-picking process in the warehouse operation needs a high number of laborers. In order to reduce this number labor, utilization must be increased; this research result shows that if the operator was provided with the optimal route to use in the picking process that productivity has increased by 29%. Optimizing order picking as suggested would improve the processes that would run more efficiently. The enhancement includes discovering the optimal route by a simulator that will directly have a positive impact on the consumption of order-picking time. Future research work can be conducted to overcome There are some limitations during conducting the current simulation model. Therefore, some modifications can be made to the simulation that was applied in this study by selecting and defining different locations to accommodate more realistic and actual situations. Moreover, the data can be used and developed by researchers in more complex situations; for example, multiple pickers in relatively large and multi-purpose warehouses, in addition to that other uncertain factors can be introduced, such as bottlenecks that occur in traffic through different paths and errors in operators. Kanban triggers can be taken into consideration by performing random optimization.

### *6.1 Practical implications of the study*

Through the gained results, a time study was made using a stopwatch to define the average picking time of each operator using simulation tool for those routes, there are a number of useful practical implications that can be acquired. It deals mainly with (a) organizational culture, (b) process re-structuring and re-engineering, (c) staff resistance to change, and d) motivation for maintaining the new way of doing business. We can summarize the main implications of the study as follows:

- ✓ Most of the companies and their warehouses need to adopt an effective digital transformation approach in the various logistics functions and move from the system of picking orders in the traditional way to the system of picking according to the future vision, bypassing only the process of updating the current technology used. Where the adoption of new and modern automation tools can result in a state of dissatisfaction among the workforce, and if it is not managed effectively and correctly, it may result in a failure in investment and a decline in performance. Therefore, it is necessary for companies to alert to increase awareness among employees and workers in them by creating an organizational culture that will raise the level of readiness and readiness to keep pace with rapid technological progress.
- ✓ Process re-structuring and re-engineering Regardless of the need of the companies and their warehouses for the need for organizational culture, the reason for failure may be attributed to the failure to adopt a policy and implement the process of re-structuring and re-engineering operations when necessary and the urgent need for that. Therefore, companies today must determine the necessary needs for their operations and various logistical activities, including the order-picking processes of different customers' requests according to the latest new and adopted technology.
- ✓ Staff resistance to change: most of the workers in the various companies and warehouses tend to resist change by replacing them with technology, due to their natural fear of putting them in the job danger zone. Typical questions are asked to the workforce who work in the logistics sector in general, and to workers in the order-picking techniques in particular when it is directed towards adopting new technologies or systems in order to maintain the workforce in companies and their warehouses and increase awareness of it through successful and effective management. In addition to adopting an effective and continuous training system to keep abreast of various developments in updating systems, which include it will facilitate the tasks and work of the various workers.
- ✓ Adopting a new motivation style for maintaining a new approach to performing the picking order process within businesses and their warehouses: next, perform a multi-level run installation for the order-picking process via simulation, it is crucial to keep the new approach to acting and executing order-picking processes in the business and in its warehouses. Finally, continuous improvement of the order-picking process should be adopted as an approach to preserve the users' interests; thus, their proposals for enhancements from the workforce are crucial with the new systems adopted such as picking order at warehouses.

This study highlights further future research work. While satisfying its goals, the research expanded and identified other possible approaches for optimization. Within the established methodology, there is still room for further optimization, such as zoning, batching and others methods to increase the productivity for the studied or investigated warehouse. Adopting and implementing this methodology, ensuring that the automatic handling process could be recommended instead of manual handling in the studied warehouse. Adding a new technology as light or sound picking for observed warehouse in this case study.

Finally, most of the case study concentrates on a specific order picking situation or decision problem. Therefore, it is not straightforward to apply approaches developed for a specific situation to another situation. General design procedures and global optimisation models of order picking are still lacking.

## References

[1] ALSMAIRAT, M.A.: The nexus between organizational capabilities, organizational readiness and reverse supply chain adoption, *Acta logistica*, Vol. 9, No.1, pp. 31-37, 2022. https://doi.org/10.22306/al.v9i1.263

[2] APTE, U.M., VISWATHAN, S.: Effective cross docking for improving distribution efficiencies, *International Journal of Logistics: Research and Applications*, Vol. 3, No.3, pp. 291-302, 2000.

[3] BARTHOLDI, J.J., HACKMAN, S.T.: *Warehouse & Distribution Science: Release 0.97*, The Supply Chain and Logistics Institute, Georgia Institute of Technology, Atlanta, GA, [Online], Available: www.warehouse-science.com [9 May 2022], 2018.

[4] BARTHOLDI, J. EISENSTEIN, D.: Using bucket brigades to migrate from craft manufacturing to assembly lines, *Manufacturing & Service Operations Management*, Vol 7, No.2, pp. 101-168, 2005.

[5] BARTHOLDI, J., EISENSTEIN, D., LIM, Y.F.: Bucket brigades on in-tree assembly networks, *European Journal of Operational Research*, Vol. 168, No. 3, pp. 870-879, 2006.

[6] BOZER, Y.A., CHO, M.: Throughput performance of automated storage/retrieval systems under stochastic demand, *IIE Transactions*, Vol. 37, No.4, pp. 367-378, 2005.

[7] CHEN, M.C., HUANG, C.L., CHEN, K.Y., WU, H.P.: Aggregation of orders in distribution centers using data mining, *Expert Systems with Applications*, Vol. 28, No. 3, pp. 453-460, 2005.

[8] CHEN, M.C., WU, H.P.: An association-based clustering approach to order batching considering customer demand patterns, *Omega International Journal of Management Science*, Vol. 33, No.4, pp. 333-343, 2005.

[9] DE KOSTER, R., LE-DUC, T., ROODBERGEN, K. J.: Design and control of warehouse order picking: A literature review, *European journal of operational research*, Vol. 182, No. 2, pp. 481-501, 2007.

[10] DE LEEUW, S., WIERS, V.C.S.: Warehouse manpower planning strategies in times of financial crisis: evidence from logistics service providers and retailers in the Netherlands, *Production Planning & Control*, Vol. 26, No. 4, pp. 328-337, 2015.

[11] DE KOSTER, R. DE BRITO, M.P., VAN DE VENDEL, M.: Return handling: An exploratory study with nine retailer warehouses, *International Journal of Retail & Distribution Management*, Vol. 30, No.8, pp. 407-421, 2002.

[12] DEKKER, R., DE KOSTER, R., ROODBERGEN, K.J., VAN KALLEVEEN, H.: Improving order-picking response time at Ankor's warehouse, *Interfaces*, Vol. 34, No.4, pp. 303-313, 2004.

[13] ENGINEERINGNOTES. COM: 4 Main Strategies Used in Routing | Networking | Computers [Online], Available: https://www.engineeringenotes.com/networking/4-main-strategies-used-in-routing-networking-computers/14914 [9 May 2022], .

[14] FARIA, F., REIS, V.: *An Original Simulation Model to Improve the Order Picking Performance: Case Study of an Automated Warehouse*, In: Corman, F., Voß, S., Negenborn, R. (eds) Computational Logistics. ICCL 2015. Lecture Notes in Computer Science(), vol 9335. Springer, Cham., International Conference on Computational Logistics, Vol. 9335, Springer, pp. 689-703, 2015. https://doi.org/10.1007/978-3-319-24264-4_47

[15] GONG, Y., DE KOSTER, R.B.: A review on stochastic models and analysis of warehouse operations, *Logistics Research*, Vol. 3, pp. 191-205, 2011.

[16] GADEMANN, N., VAN DE VELDE, S.: Order batching to minimize total travel time in a parallel-aisle warehouse, *IIE Transactions*, Vol. 37, No.1, pp. 63-75, 2005.

[17] GU, J., GOETSCHALCKX, M., MCGINNIS, L.F.: Research on warehouse design and performance evaluation: A comprehensive review, *European Journal of Operational Research*, Vol. 203, No. 3, pp. 539-549, 2010.

[18] HABAZIN, J., GLASOVIC, A., BAJOR, I.: Order Picking Process in Warehouse: Case Study of Dairy Industry in Croatia, *PROMET-Traffic & Transportatio*n, Vol. 29, No. 1, pp. 57-65, 2017.

[19] HALL, R.: Distance approximation for routing manual pickers in a warehouse, *IIE Transactions*, Vol. 25, No. 4, pp. 76-87, 2007.

[20] HERAGU, S.S., DU, L., MANTEL, R.J., SCHUUR, P.C.: Mathematical model for warehouse design and product allocation, *International Journal of Production Research*, Vol. 43, No. 2, pp. 327-338, 2005.

[21] HSU, C.M., CHEN, K.Y., CHEN, M.C.: Batching orders in warehouses by minimizing travel distance with genetic algorithms, *Computers in Industry*, Vol. 56, No. 2, pp. 169-178, 2005.

[22] HWANG, H., OH, Y.H., LEE, Y.K.: An evaluation of routing policies for order-picking operations in low-level picker-to-part system, *International Journal of Production Research*, Vol. 42, No. 18, pp. 3873-3889, 2004.

[23] LE-DUC, T.: *Design and control of efficient order picking processes*, PhD thesis, Erasmus University Rotterdam, 2005.

[24] KIM, T.Y., DEKKER, R., HEIJ, C.: Improving warehouse labour efficiency by intentional forecast

bias, *International Journal of Physical Distribution & Logistics Management*, Vol. 48, No. 1, pp. 93-110, 2018.
https://doi.org/10.1108/IJPDLM-10-2017-0313

[25] LAHMAR, M.: *Facility Logistics: Approaches and Solutions to Next Generation Challenges*, Auerbach Publications, Chapter 11, 2007.

[26] LE-DUC, T., DE KOSTER, R.: Layout optimization for class-based storage strategy warehouses, *Supply Chain Management-European Perspective*, Vol. 2005, pp. 199-222, 2005.

[27] PETERSEN, C.G.: An evaluation of order picking routeing policies, *International Journal of Operations & Production Management*, Vol. 17, No. 11, pp. 1098-1111, 1997.

[28] RICHARDS, G.: *Warehouse management: a complete guide to improving efficiency and minimizing costs in the modern warehouse*, London: Kogan Page, 2nd ed., 2014.

[29] ROODBERGEN, K.J., KOSTER, R.: Routing methods for warehouses with multiple cross aisles, *International Journal of Production Research*, Vol. 39, No. 9, pp. 1865-1883, 2001.

[30] SINISALO, T.: *Improving Efficiency of the Order Picking Process in the Case Company Warehouse*, Master's Degree, Helsinki Metropolia University of Applied Sciences, 2016.

[31] VAN DEN BERG, J.P.: *Integral Warehouse Management*, Lulu. com, 2007.

[32] VAN GILS, T.: Ramaekers, K., Caris, A., Cools, M.: The use of time series forecasting in zone order picking systems to predict order pickers' workload, *International Journal of Production Research*, Vol. 55, No. 21, pp. 6380-6393, 2017.

[33] VAUGHAN, T., PERTSON, V.: The effect of warehouse cross aisles on order picking efficiency, *International Journal of Production Research*, Vol. 37, No. 4, pp. 881-897, 1999.

[34] KIM, T.Y., DEKKER, R., HEIJ, C: Improving warehouse labour efficiency by intentional forecast bias, *International Journal of Physical Distribution & Logistics Management*, Vol. 48, No.1, pp. 93-110, 2018.

[35] GOKCECICEK, T., GONCA, T.: Order picking systems in warehouse management: a literature review, *DergiPark*, Vol. 14, No. 3, pp. 15-31, 2012.

[36] TOMPKINS, J.A., WHITE, J.A., BOZER, Y.A., FRAZELLE, E.H., TANCHOCO, J.M.A., *Facilities Planning*, NJ: John Wiley & Sons, 2003.

[37] WON, J., OLAFSSON, S.: Joint order batching and order picking in warehouse operations, *International Journal of Production Research*, Vol. 43, No. 7, pp. 1427-1442, 2005.

[38] VAN HOEK, R.I.: The rediscovery of postponement a literature review and directions for research, *Journal of Operations Management*, Vol. 19, No. 2, pp. 161-184, 2001.

**Review process**
Single-blind peer review process.