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MEE 2.0: ICLT2022
International Virtual Colloquium on Multi-Disciplinary Research Impact (3rd Series)
International Conference of Logistics and Transportation
Best Western i-City Shah Alam, Selangor, Malaysia, 05-06 Oct2022

Modelling the Inner Warehouse Shortest Route Planning using Dynamic Programming Block

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Abstract
Fulfilling the customer requirement has always been of utmost concern to logistics service companies, namely those providing warehouse and transportation services. In the warehouse, inner transportation problem affects its performance. Order picker problem is one of the problems that involves the transportation problem within the warehouse. The problem can be handled properly by having proper storage assignment, proper tasking allocation and optimal routing for inner warehouse vehicles' movement. This study proposed a modified Dynamic Programming model to determine the shortest route for the order pickers in completing and fulfilling the customers' orders. The model shows stable solutions for numerous orders.

Keywords: Order picking, dynamic programming, inner warehouse transportation

DOI : https://doi.org/10.21834/ebpj.v7iSI9.4314

1.0 Introduction
Nowadays, orders can be made through typical style by going to the shop and also via online. Because of the ordering process is fast and can be made 24 hours a day, customers also expect a fast return in delivery. As time change, populations, environments, demand's needs, and trends might change. All types of organizations are now dealing with this system and adjusting their new norm of supplying needs to the customers. Their organizations need to make sure their warehouse management system is able to provide fast and efficient service to meet the standard of this new situation. This may sometimes need a big 360-degrees change in the style of managing stocks, picking desired items, and maybe effects the pattern of delivery service to respective customers.

Traditionally, the aim of logistics was to make sure the supply of needs to customers are produced and delivered at the right time and at a right quantity. The key components of achieving these objectives are on how effective the delivery service of products and the efficiency of managing the inventories in a warehouse. Transportation is a mechanism of delivering the right product at the right place by moving them from one location to another. For instance, a company with a big warehouse, they have their own transportations in each department. Usually forklifts or maybe trucks are needed to transport their material or finished goods to depot.

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2.0 Literature Review

A critical research area in current warehouse management practice is to find ways in increasing picking productivity and make it work effectively. Typically, a warehouse consists of various areas. These include shipping and receiving areas, bulk storage and order picking areas. Shipping areas or transporting areas is where all the items are ready to be delivered to other locations. Receiving areas sometimes is placed at the same area as the delivery area. Some companies may need a bulk storage if they involved with bulky items and their product can be keep longer. Finally, the order picking area consists of retrieving individual items from storage on the basis of customers' orders. According to Anđelković & Radosavljević (2018). , order picking process is considered as one of the most laborious and costly activities in a warehouse. Thus, proper and systematic management are crucial in satisfying the needs of customer and also the management. It is stated that 55% of all operating costs in a typical warehouse can be attributed to order picking. This is based on a study done in United Kingdom, as mentioned in Dharmapriya and Kulatunga (2011). This process may be complex and leads to high budget and any ineffective system could stop or turn down the warehouse from productive operation and further innovation. In spite of many studies have been done in order to improve the order of picking operation, to manage it efficiently have become more complex (Wang et al., 2020; Ran et al., 2020). However, each order-picking requirement may be different from other warehouse operation and one success solution to company A may not necessarily suit company B. Thus, there is a need in bridging the gap that may comply to suit all types of order picking in warehouse operation. Boysen et al. (2019) stated that more than 80% of all orders in the warehouses are processed and picked manually. Even though nowadays robotics and many intelligent automated systems seems to slowly been used in order picking process of a large warehouse, there are still in need of manual order picking by humans in the near future. Using automated system may also incurred cost of maintenance, and small companies may not afford to use this system.

In general, the manual order picking systems can be categorized as part-to-picker and picker-to-part system (Gajšek et al., 2020). In part-to-picker, products are moved from the storage area and then delivered to the picking bays. Each bay may receive more than one order for each item. However, according to Lee & Murray (2019), this method may increase labor cost because the waiting time for order picker may arise since they have to wait for the items to be delivered to their picking location. Sometimes, this system may be extended to automated storage and retrieval system (AR/RS) using crane or large mechanism in retrieving bigger loads. Sometimes, the loads may also be placed in a higher level in a warehouse.

Next, the automated system on the other hand, may look easier and able to cater and handle big job. Plus, the number of human work force may be reduced. This system usually involves automated guided vehicle (AGV) which are commonly used to transport bulk materials mainly for manufacturing, distribution or warehousing system. The advantages of using this AGV include reliable, automatic operation, flexible in handling materials, reduce damage of materials, and may also be integrated with other automated system, (Deng et al., 2018). Rapid research progress has been witnessed following this technology. However, using such machinery do have some drawbacks. According to Soffar (2019), firstly, the installation of the machine is costly especially for small companies, might find it cost-prohibitive. Secondly, the maintenance of the machinery is an ongoing cost as in the use of AR/RS. These systems also require periodic repairs. Say they experience technical breakdown; the need of human work force is need to cover the job of the AGVs. In the end, the need of manual storage system and manual order picking cannot be totally ignored.

This study involved the development of the adjusted mathematical model for the order picker with capacity constraint and limited picking capacity. The model was designed to estimate the travel time of an order picker based on a normal shift of 8-hours a day, taking into consideration the number of pickers, resting time and their picking capacity. In this case, we only consider the manual order picking which the picker will need to walk through the aisle in completing their order list. Currently, the order item is considered small and the company may consider to increase the number of orders with current capacity of workers. The database for the order items for everyday normal working hours was created. Then the adjusted mathematical model was developed. The adjusted mathematical model considers the limited picking capacity for each picker and limited number of pickers involved at particular time. Then, the Dynamic Programming method (DP) was incorporated in the adjusted model to find the shortest path and travel time for each picker (Nordin et al., 2017). As a result, the pickers may know their number of items to be picked and which route to be taken in order to complete the customer's order. DP method was chosen since it is capable to solve the all-pairs shortest path problem in a sparse, weighted, directed graph.

3.0 Methodology

The data is obtained from an automotive manufacturing company in Serendah Selangor. Data includes the current shift of the warehouse and number of order pickers assigned at each floor. The company has a day and night shift where order for the evening is prepared in the morning; while any order for the next day is settled during the night shift. Data also provides the floor plan for the warehouse which currently is the best practice applied in the manufacturing company.

3.1 Data Collection

The floor plan as given in Fig.1 is the current layout of the warehouse. In finding the shortest path for the order picker to collect all the orders made in time, proper routing is vital.

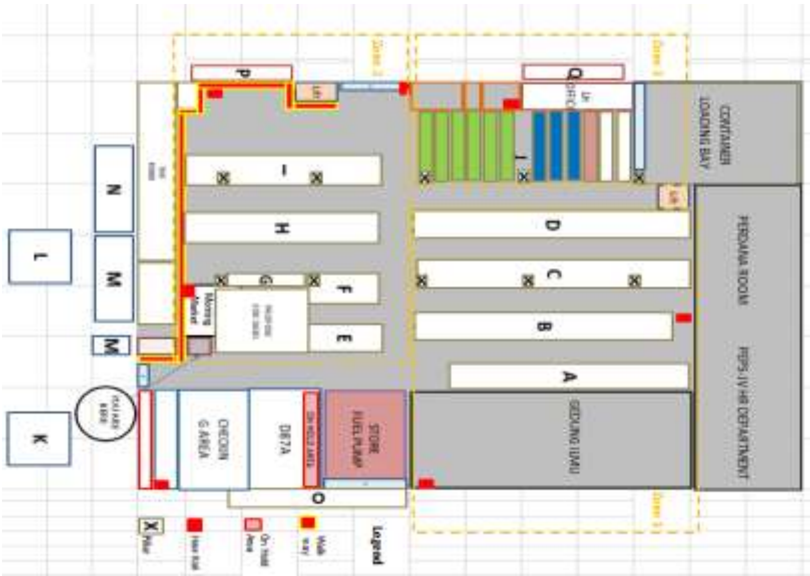

Fig. 1. Floor plan of the Automotive Manufacturing Company

In this automotive company, there are mainly two floors in the warehouse. On the ground floor is where all the big parts are placed on shelves. Should any order is made by a customer, an order picker will use a forklift to deliver the big parts onto a pallet. Next, this pallet will be transferred into the delivery truck. There are 10 forklifts available in the automotive company. This number of forklifts is hoped to reduce waiting time to retrieve the order. All the collected orders will be arranged in a pallet and each pallet can be filled to seven equal parts and ready to be delivered to the customer. Normally for one delivery truck, eight to ten pallets can be filled to complete one trip or depending on the size of the parts. The number of trips in a day depends on the number of orders made by the customers. Zone 2 and zone 3 are located in this area, which is the ground floor.

On the other hand, in the first floor which holds Zone 1 is where all the small parts are placed. Here, the order retrieved will be picked manually by the order pickers. There are 7 order pickers all together. The procedure starts with collecting order forms from customers. Next, the order picker will print the order form and collect the needed item accordingly. The order picker will standby at their particular shelf and supposedly they are already familiar with the area. This helps to save time when picking the order and thus, the response time can be reduced. Once the order is completed, the items are placed in the 'Standby for Delivery' area to be finalized, wrapped and tagged before they are handed to the delivering units. The flow of order picking in the area under study is best described in Fig. 2.

3.2 Developing Route Network for The Automotive Manufacturing Company

In the process of developing the shortest path for the order picking in the warehouse, proper representation of the routes involved in the network is a main concern. Generally, this network refers to a path with fixed nodes or vertices and intersected with edges or arcs. Under the purpose of this study, nodes are defined as an item placed in the warehouse, while edge is an aisle of item stored location that serves as the directional link between them. Each edge is associated with a particular weight, which is the distance length between two adjacent nodes (items). The weight must be nonnegative since the travel time or distance, by definition, must be nonnegative.

Once the network is completed, an algorithm to find shortest path is applied to determine the shortest path through the network. Mohd Nordin (2010), there are many other algorithms that may work to solve the problem. In warehouse scenario, all the items in the order list must be picked. Hence, each node or its store location of an item must be visited. In this study, the Dynamic Programming (DP) Block is adapted to find the shortest path in this situation. The results are hoped to bring contribution in the literature as well as the manufacturing company with similar procedure in minimizing the total time in order picking.

3.3 The DP Method for One Block

For DP method for one block, we consider four subaisles based on the layout plan. Figure 3 shows the stored locations for the item stated in the order list. In total, 9 items need to be collected from this block starting from the order list station and stop until the picker arrive at the packaging point. The length of each block is mentioned in centimetres. The length of each block is 1310 cm. The distance between two neighbouring subaisles is 360cm. In this case, $l=1$ and $r=4.$ In this occasion, $A=b_{i1}$ is denoted as the starting point, and $D=b_{i3}$ is the ending point. The route starts at the left-most subaisles (l) which is b_{i1}, and ends at the right-most subaisles, b_{i3}. All the values and distance is transformed to a possible nodes and edges. b_{i1}, b_{i2}, b_{i3} and b_{i4} are the nodes from the front of the block while a_{i1}, a_{i2}, a_{i3} and a_{i4} are the nodes from the back of the block. Nodes *1* to *9* denotes the location of the item needed.

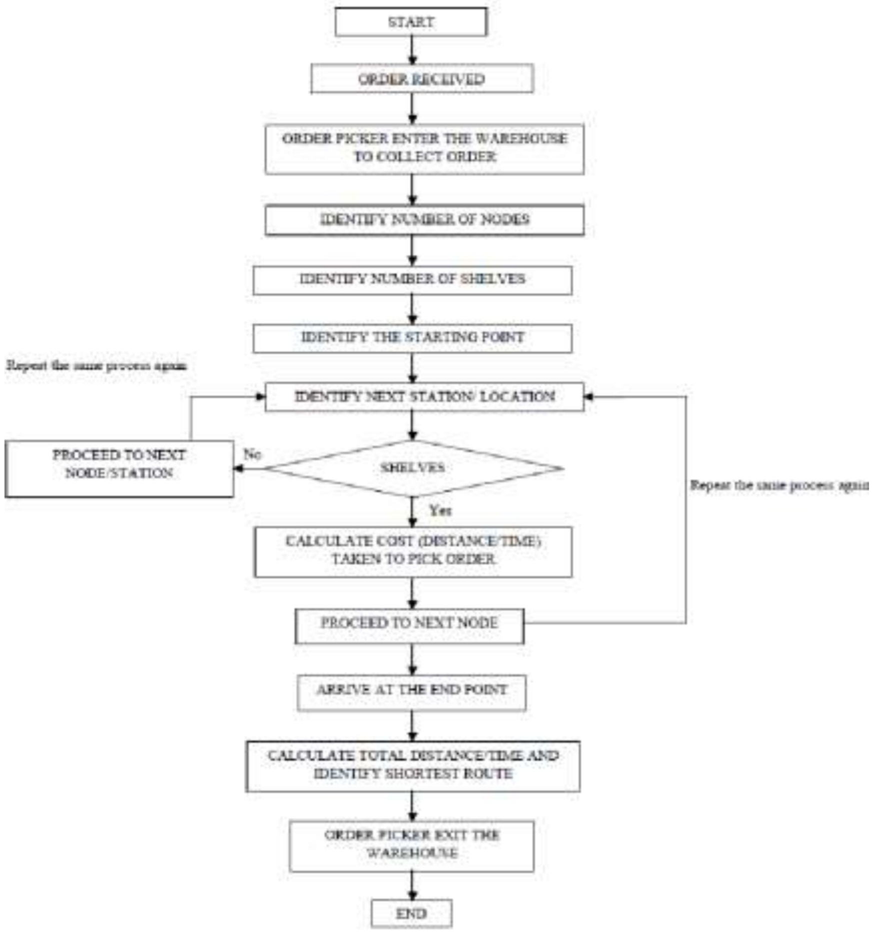

Fig 2: Flow chart of the order picking process

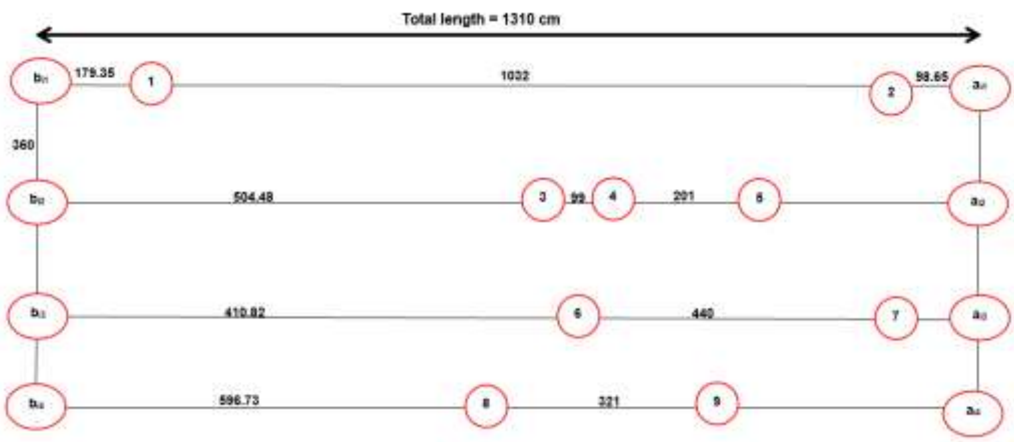

Fig. 3. Routing network using DP method for Zone 1

4.0 Results and Discussion

The process starts with identifying the node that is assumed to be the block farthest from the depot (packaging point), that is b_{i1}, thus we start with two partial routes L_1^a and L_1^b. L_1^a starts at node b_{i1} and ends at node a_{i1}. This process involved transition t_1

with total distance of 1310cm. This can also be written as $c(t_1)=1310.$ On the other hand, L_1^b means we start and ends at the same node b_{i1} and consists of transition t_3. In this case, the total distance or $c(t_3)=2422.70.$

Next, there are two possibilities of creating L_2^a, namely $L_1^a+t_a+t_4=1310+3.6+[201+99+504.48]\times 2$ and $L_1^b+t_b+t_1=2422.70+3.6+1310$ which result in 2922.56 cm and 3735.6 cm respectively. The shortest value between the two will be chosen as the next possible shortest path. In this case, the current $c(t_1)=2922.56.$ The same procedure need to be repeated to find L_2^b. The possible path for L_2^b can be achieved via $L_2^b=L_1^a+t_a+t_1$ and $L_2^b=L_1^b+t_b+t_3$. The calculation can be seen clearer using the diagram below:

$$
\begin{aligned}
&=L_1^a+t_a+t_1\\
&=1310+3.6+1310\\
&=2623.6
\end{aligned}
$$

$$
\begin{aligned}
&=L_1^b+t_b+t_3\\
&=2422.70+3.6+[201+99+504.48]\times 2\\
&=4035.26
\end{aligned}
$$

Thus, from the findings, $c(t_3)=2623.60$ is chosen as the next shortest distance. The same process is repeated to find L_3^a and L_3^b. The end result for L_3^a is $L_2^b+t_b+t_1=3937.2$ and L_3^b is $L_2^a+t_a+t_1=5049.20$ respectively.

For the last subaisle *r*, we determine L_r^b by comparing the previous shortest value of L_3^a and L_3^b. In this step there is no need to find L_r^a since all the items have been picked in a block and we just need to continue to end the picking point b_{i3}. The value of $r=4$ represents the right most aisle in the layout. Thus, L_4^b can be calculated as:

$$
\begin{aligned}
&=L_3^b+t_a+t_1\\
&=5049.20+3.6+1310\\
&=6362.80
\end{aligned}
$$

$$
\begin{aligned}
&=L_3^a+t_b+t_3\\
&=3937.20+3.6+[321+596.73]\times 2\\
&=5776.26
\end{aligned}
$$

Based on the value obtained, it is clearly shown that L_4^b can be achieved via $L_3^a+t_b+t_3$. The total distance from b_{i1} to b_{i3} can be achieved via route b_{i1} ⊛ a_{i1} ⊛ a_{i2} ⊛ b_{i2} ⊛ b_{i3} ⊛ a_{i3} ⊛ a_{i4} ⊛ b_{i4} with the total distance of 5776.36cm. Routing representation can be seen in Figure 3.

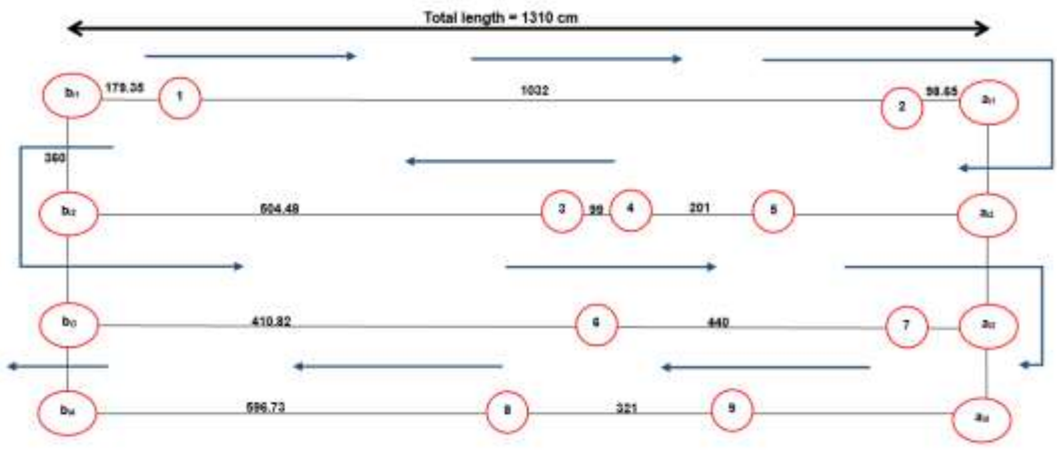

Fig. 4. Shortest path using DP method

On the whole, the DP method did produce better results due to its flexibility of choosing path in the algorithm and considering all possible paths. In DP, the picker will follow the path that has already organized in the warehouse. In this case, all impossible solutions can be eliminated. Furthermore, the problem is solved stage by stage. Only for this purpose, the application of DP does not consider penalty for turning. Hence, for future research, the penalty at the turning aisle needs to be considered. On top of that, this study only considers a random order (Löffler et al., 2020; Nordin et al., 2022). In reality, there will be more than one order and the items stored locations might have different structure. This network can also be represented with different settings and the layout may be reduced to three subaisles altogether depending on how the items is organized in the manufacturing company.

5.0 Conclusions

Process of handling and maintaining goods that comes in and out of the warehouse is a costly operation. In addition, the order picking process also contributes more than half time consumption in a warehouse. Thus, to keep the costs as low as possible, it is essential that quantity and placement of the items are accurate. To have efficient warehouse processes, the company must clearly define the warehouse in terms of layout, routing, scheduling, storage assignment as well as internal replenishment information. Thus, in this study, the DP method is proposed for shortest route planning and the result obtained is to test whether the DP method is reliable in managing the order picking process. Hence, from here we may also check whether the objective of obtaining minimum travel distance is satisfied. Based on the results obtained, the modified DP method provide better results as, in reality, the picker may have to make a stern or choose other path in order to arrive to the stored location. In addition, the shortest path obtained already considers every turn, cross aisle and all possible path the picker can go.

Overall, the study offers an approach to efficient order picking strategy in any warehouse management system with similar scenario. In addition, any parties including both the government and the public will benefit through the proposed model and algorithm which is capable of enhancing the quality of the warehouse management system. Both parties can get the benefits by minimizing the cost of services and maximizing the profit made for a management involved in supply chain management especially in the advance technology where rapid response is vital. Rapid response is important in a decision-making situation because demands is uncertain and during this new norm with online shopping and such, helps management to control their stock keeping and storage assignment. If the service of the warehouses can be enhanced, the cost of production can also be minimized while the warehouse management system can be improved.

Acknowledgements

We would like to express our gratitude to Malaysia Institute of Transport (MITRANS), Universiti Teknologi MARA (UiTM) Shah Alam, Selangor Malaysia, for supporting this research, as well as ReNeU UiTM for the PYPB incentive.

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