ANALYSIS OF ORDER-PICKING IN WAREHOUSES WITH FISHBONE LAYOUT

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ABSTRACT

Recently new innovative warehouse layouts are suggested that do not follow usual restrictions of ubiquitous traditional designs. One of them, called fishbone layout, showed potential to reduce travel distances in unit-load warehouses by more then 20%. In manual-pick order-picking systems with case and item picking from multiple locations different routing policies are used. In this paper we present the preliminary results of performance analysis of the simplest but also most common in practice routing policy for picking from multiple locations, in comparison with performances in traditional layouts.

Keywords: Order-picking, Warehousing

1. INTRODUCTION

It is well known that logistic costs have important influence on final successfulness of any company. According to the Logistics Cost and Service 2007 study [1], in western countries these costs represent almost 10% of sales. Warehousing, along with transportation and inventory carrying, is one of the three major drivers of total logistics cost, with 21% in US and 37% in EU. Order-picking process, defined as the process of retrieving items from storage locations in response to a specific customer request, is the most laborious and the most costly activity in a typical warehouse, with up to 55% of warehouse total operating costs (Tompkins et al. [2]). With a direct link with speed of delivery, it influences service level too. Therefore, it is very important to put some efforts on reducing order-picking costs and cycle time, *i.e.*, to improve order-picking efficiency. It is possible to improve operational efficiency of order-picking using appropriate operating policies. The research in this area has grown rapidly recently and considerable literature exists on various methods of picking an order as efficiently as possible (de Koster et al. [3]).

The time to pick an order can be divided on three components: time for traveling between items, time for picking the items and time for remaining activities. The fact that about 50% of total order-picking time is spent on travelling (Tompkins et al. [2]) gives a potential to improve order-picking efficiency by reducing travelling distances. Most methods of improving operational efficiency of order-picking focuses on reducing travel times, and can be categorized into one of three groups of operating policies: routing, storage and batching (Roodbergen and Vis [4]).

Routing methods determine the sequences and routes of travelling, trying to minimize total travel distances. Storage methods, or assigning items to storage locations based on some rules, could also reduce travel distances compared to random assignment. Order batching methods, or grouping two or more customer orders in one picking order, are also very efficient in reducing total travel distances. All methods mentioned are well-known and proven in improving order-picking efficiency. However, the performances depend greatly on the layout and size of the warehouse, the size and characteristics of orders and the order-picker capacity. The performance of a particular method also depends on the other methods used, therefore it is important to understand their mutual interactions (Dukic and Oluic [5]).

For a given layout of the picking area, characteristics of orders and other influencing factors, a good mix of order-picking methods can be implemented. However, analysis of methods showed non negligible influence of layout on performances of particular method or mix of methods. All papers regarding analysis of order-picking methods in manual-pick order-picking systems imply traditional layouts. Just recently engineering professors Russell Meller and Kevin Gue proposed radically new, innovative warehouse layouts that could reduce retrieval times in pallet picking (Gue and Meller [6]).

In this paper we present the preliminary results of analysis of the simplest but also most common in practice routing policy for picking from multiple locations, in so called "fishbone" innovative layout, in comparison with performances in traditional layouts. The paper is divided as follows. In Section 2 we give brief description of developed routing methods. In Section 3 we present the traditional and innovative layouts, with review of former research results regarding influence of layout on traveling distances in order-picking. In Section 4 examined situation and results of analysis are presented, while conclusions are drawn in Section 5.

2. ROUTING METHODS

Routing of order-picker concerns the movement of the order picker from location to location to retrieve products. The objective of routing policies is to sequence the items on the pick list to ensure a good route through the picking area – as short as possible. The problem of routing order pickers in a warehouse is actually a special case of the Travelling Salesman Problem. The order picker starts at the depot, has to visit all pick locations and finally has to return to the depot. For the type of warehouse shown in Fig. 1 left, Ratliff and Rosenthal [7] developed an algorithm that results in a shortest possible, thus optimal route, while Roodbergen and de Koster [8] developed an algorithm for shortest route in warehouses with 2 blocks (with additional cross aisle in the middle), type shown in Fig. 1 middle and right.

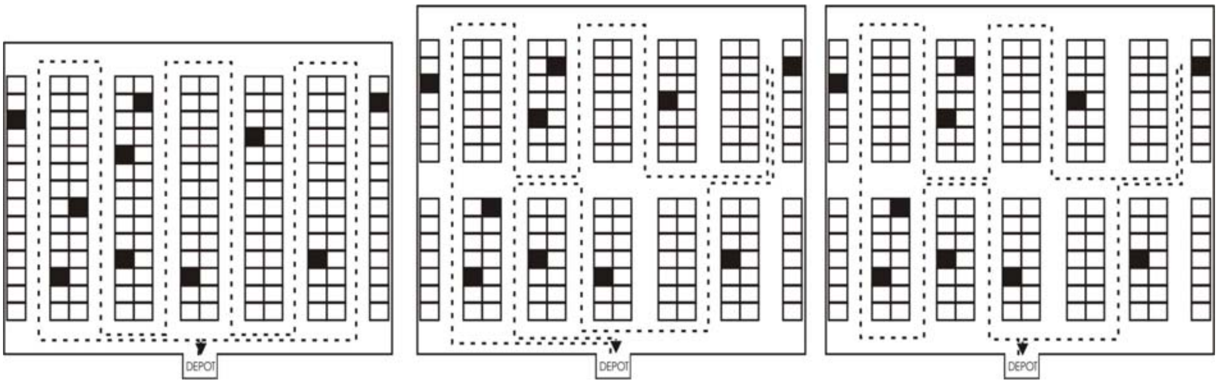

Fig. 1: Examples of traditional layouts and picking routes using S-shape routing policy

Besides the objective of short routes, there are other considerations. Order-picker has to execute the route, so it should be easy to understand and follow, which also could lead to enhanced productivity. This is probably the reason while most warehouses use heuristic routing policies. There are several heuristic routing methods (policies) developed and used in practice. The simplest routing heuristic is the *S-shape* policy. When this method is used, the order picker enters every aisle where an item has to be picked and traverses the entire aisle. Aisles where nothing has to be picked are skipped. An exception is made for the last aisle visited, in case the number of aisles to be visited is odd. In that case a return travel is performed in the last aisle visited. For descriptions of other routing policies and their evaluations please refer to the literature listed in de Koster et al. [3].

3. ORDER-PICKING AREA LAYOUTS

Traditional warehouse/order-picking area layouts are layouts we could find today in majority of warehouses. The basic form is with parallel aisles, a central depot (pick up/delivery point), and two possibilities for changing aisles, at the front and at the rear of warehouse, shown in Fig. 1 left. Modifications of this basic form are usually with adding one or more additional cross aisles. In this case we refer to a layout with multiple cross-aisles. The layout with one middle cross aisle is shown in Fig. 1, middle and right.

As already said, evaluation of routing policies showed that layouts of order-picking area have significant influence on resulting traveling distances. For a given storage capacity, one can find optimal layout regarding number and length of aisles (Roodbergen and Vis [4], Caron et al. [9]). Results of previous researches showed also that adding one or more cross aisles could benefit the total traveling distances, and that is also possible to find optimal number of cross aisles (Vaughan and Petersen [10]). Although note that adding additional cross aisles increases required storage area (and therefore related costs).

The traditional design of warehouse layout is based on a number of unspoken, and unnecessary, assumptions. The two most restrictive are that cross aisles are straight and must meet picking aisles only at right angles, and that picking aisles are straight and are oriented in the same direction. In Gue and Meller [6] authors show that those design assumptions, neither of which is necessary from a construction point of view, limit efficiency and productivity because they require workers to travel longer distances and less-direct routes to retrieve products from racks and deliver them to designated pickup-and-deposit points. In layout that maintains parallel picking aisles, but allows the cross aisle to take different shape, the expected distance to retrieve a single pallet is 8-12% less than in an equivalent traditional design, depending on the dimensions of the warehouse. They named such layout Flying-V layout. Relaxing a second assumption that picking aisles must be parallel, they derived so called fishbone layout. Example of such layout is shown in Fig. 2. The fishbone layout also incorporates the V-shaped cross aisles, with the V extending across the entire warehouse. The picking aisles below the V are horizontal, while the aisles above the V are vertical. The expected travel distance in a fishbone design can be more then 20% less than in a traditional warehouse. Similarly to traditional layouts with cross aisles, these alternative layouts also require a facility 3-5% larger than does the basic traditional layout, which was designed to minimize the footprint of a warehouse.

4. ORDER-PICKING FROM MULTIPLE LOCATIONS IN FISHBONE LAYOUT

Despite the great potential of new innovative unit-load warehouse designs in reducing traveling distance in pallet picking (single command), the question is what would be the distances of routes for case and item picking from multiple locations in such layouts (multiple command), compared to the traditional layouts. To address this question we tried to analyse routing of order-pickers in fishbone layout. In this paper some preliminary results of analysis are presented. We were restricted on one chosen layout, which is optimal for pallet picking, and the most simplest and used in practice routing method: S-shape. The first problem we encountered was how to define the routing algorithm in fishbone layout. The description for S-shape routing policy in layouts with multiple blocks is as follows (Roodbergen and de Koster [11]). The order-picking route starts at the depot. It goes to the front of the left-most main aisle that contains at least one item. This main aisle is traversed up to and including the block farthest from the depot, that contains at least one item. If the current block contains at least one item, order-picker goes to the left most aisle containing items or to the right most aisle containing items, whichever is the closest. Then goes from one aisle to the next and traverse any aisle containing items entirely. After picking the last item, it returns to the front of the block. If this block contains no items, it traverses the aisle of this block that is closest to the current position. This procedure is repeated for all blocks until the block closest to the depot has been considered. Finally, order-picker returns to the depot.

First, it is impossible to say which block in fishbone layout is farthest from the depot, and which is closest to the depot. Second, examining the resulting routes in traditional layout with middle cross aisle (with 2 blocks) and depot located in the middle of the front aisle, we noticed the tendency of above algorithm to create longer routes then expected, due to unnecessary increased across aisle component of routes, as illustrated in Fig 1 middle. Therefore, we suggest modification of algorithm in such situations. The layout is considered as a 3-block warehouse (left down, up, right down). The order-picker starts at the depot, and visits blocks in clockwise manner. In each block aisles containing the items to be picked are also visited in clockwise manner. After picking last item in a block, it goes to the cross aisle in front of the next block, and finally returns to the depot. The resulting route is shown in Fig. 1 right. Same algorithm is easy applicable to the fishbone design, as illustrated in Fig. 2.

For analysis we have chosen the layout of 576 locations per layer. Due to the simplicity of distance calculation, dimension of a location is 1x1 meter and the width of all aisles is 2 meters. The traditional layout was with 12 main aisles (total width across aisles 48 meters) and the length of main aisles 24 meters (24 locations per row). With the location of a depot in the middle, it is the optimal layout for single command picking. Comparable fishbone design is shown in Fig. 2.

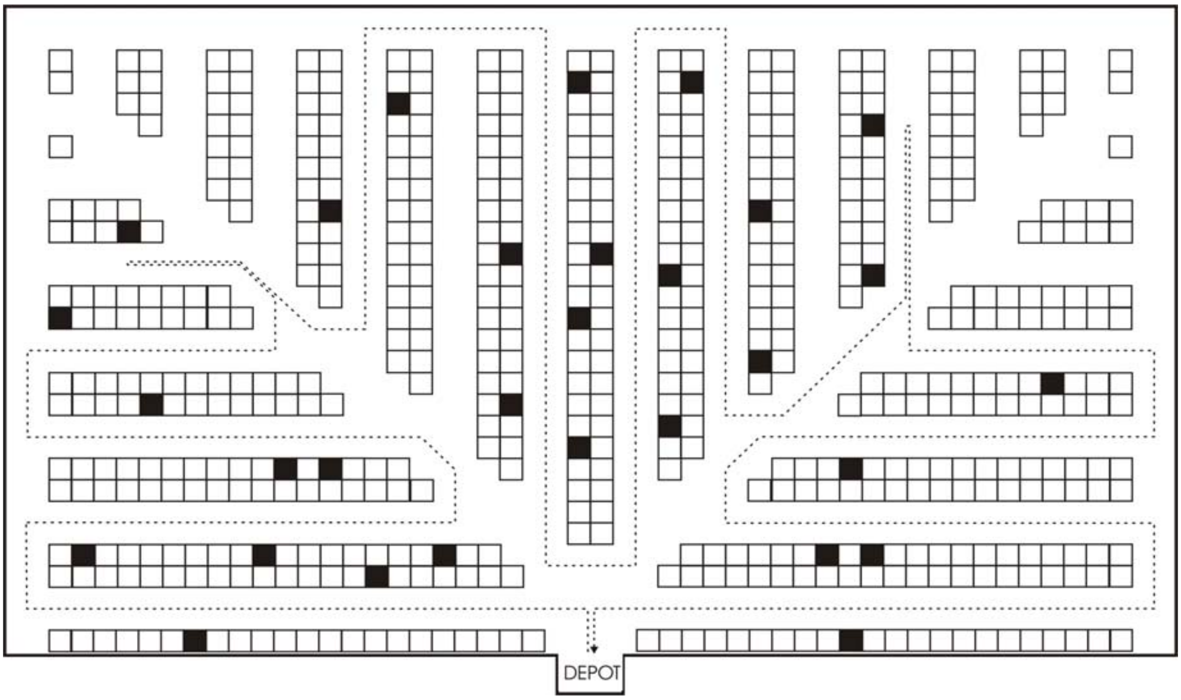

Fig. 2: Example of picking route in examined fishbone layout

To determine the average traveling distances we used simulation. For a set of orders we generated locations in layout (based on random storage) and calculated traveling distances. The analysis was conducted for 2 order sizes, one relatively small with 10 picks per order, and one large with 30 picks per order. For the purpose of better understanding of routes' nature and comparison, we calculated also both components of travel – within aisle (along main aisles) and across aisle (travel in cross aisles). The results are given in Table 1.

As it was expected for examined cases, adding middle cross aisle in traditional layout decreases average routes. For both order sizes density of pick locations in 12 main aisles is not high, and adding middle cross aisle will eliminate some unnecessary travel in main aisles without pick locations. But also note that the percentage of reduction for order size 30 (12.5%) is smaller then reduction for order size 10 (25%). Increasing the order size (increasing the pick density – average distance between picks) there would be the point where adding middle cross aisle is not beneficial.

Table 1: Results of analysis

Order size	10			30		
Traveling distance (m) / Layout	Within aisle	Across aisle	Total average	Within aisle	Across aisle	Total average
Traditional (basic)	181.3	77.4	258.7	289.1	86.7	375.8
Traditional with middle cross	116.5	77.4	193.9	242.3	86.7	329.0
Fishbone	155.6	71.9	227.5	268.7	83.2	351.9

The resulting average routes in fishbone layout are also shorter compared to the basic traditional layout. However, it seems that adding V-shaped cross aisle has smaller potential then adding middle aisle. Across aisle component of average route was even slightly shorter, but reductions of within aisle travels are not as much as for layout with middle cross. That could be explained as follows. First, with fishbone layout we actually have 3 blocks, therefore more aisles then in 2 block layout with middle aisle. Performances of S-shape routing policy are much better in situations with higher number of picks per aisle due to mandatory travel through full length of aisles. Second, fishbone layout creates blocks of aisles with different lengths, with higher probability that pick location is in longer aisles then in shorter aisles. Therefore in total, the order-picker should traverse more aisles where average length of visited aisle is longer then in traditional layout with middle aisle.

The required storage area of fishbone layout is also increased in comparison with traditional layout with middle cross aisle. V-shaped cross aisle itself causes some loss of storage area, but main increase is due to two additional rear aisles on left and right side of the layout. In examined situations, the required area for fishbone layout was 16% higher then for basic traditional layout, and 8% higher then for traditional layout with middle aisle.

5. CONCLUSIONS

Fishbone layout is with no doubt excellent layout for pallet picking (in our examined case the reduction of single command travel is 13.8%), already implementing in real warehouses. However, in warehouse with case and item picking from multiple locations fishbone layout results in larger routes then traditional layout with straight, right angled cross aisle, at least if S-shape routing policy and random storage are used. But note that longer routes could be due to the nature of S-shape routing policy, which seems not favorable for fishbone layout. More research is needed, regarding other routing policies, storage methods, the shape and size of warehouse, to more completely validate this interesting new layout.

Gue and Meller are also working to develop optimal layouts for warehouses that involve case and item picking. Those designs may be totally different. Warehouse designers should be aware of all advantages and disadvantages of different layouts and, depending on the given situation and importance of objectives, choose the most appropriate one.

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