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A Logistics Center Order Picking and Replenishment Method: A Case Study

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Abstract: The main activities of most logistics centers are: (1) receiving materials from suppliers, (2) receiving orders from customers, (3) picking customer orders, (4) replenishment relocation, and (5) distribution of the orders. Order picking and replenishment activities have been reported to be two of the most labor-intensive activities and a source of significant waste. The purpose of this paper is to develop a generic strategy for improving the efficiency of activities (3) and (4) termed, a logistics center order picking and replenishment method (LCOPRM). Many studies simulate picking procedures using models that often make reductive assumptions about real events. The LCOPRM method requires real world order picking and replenishment applications rather than simulation models. The LCOPRM was tested in a large-scale logistics center for an office equipment retail company. The results show that by implementing the LCOPRM, the picking route for 51% of customer orders was minimized by 50%, the picking route for the other 49% of customer orders remained unchanged and the number of replenishment tasks was reduced by 38.75%. The findings identified through our analysis allow the implication of the LCOPRM by directing limited resources efficiently, and improving the performance measures of logistics centers.
Keywords: Logistics center, Order picking, Design and planning, Interior design, Case studies.

1. Introduction

In the face of increasing international production and trade globalization, logistics centers are fast becoming central to the efficiency of retail supply chain management [1]. A logistics center is a specific area where all the activities relating to transport, logistics and goods distribution are performed by various operators and tools. Dedicating specific areas to these activities implies planning the space and rationalizing infrastructures to optimize area utilization [2]. The warehouse of a typical logistics center consists of the following areas: distribution, offices, reception, picking and packaging (Figure 1). Usually, in practice, the interior design of the picking area is divided into two zones: a long-term storage zone and short-term storage zone that serves as the picking location. The flow of items or stock keeping units (SKUs) throughout the warehouse passes through the following process: receiving, storage, order picking and distribution [3]. Order picking involves assigning inventory to order lines, releasing orders to the floor, picking the items from storage locations, and the dispersion of the picked items [4]. The main activities of a logistics center are: (1) receiving materials from suppliers and storing the materials in the long-term storing zone, (2) preparing orders from external and internal customers for picking, (3) picking, routing and packaging customer orders, (4) locations replenishment, i.e., moving items from the long-term storage to the short-term zone for future picking, and (5) distribution of the orders to the appropriate customers. Among logistics center operations, order picking and replenishment has been reported to be two of the most labor intensive activities. Inefficient picking and replenishment processes can be a source of significant waste. This paper presents a generic strategy for eliminating waste by improving the efficiency of these activities using a logistics center order picking and replenishment method (LCOPRM). Improving order picking efficiency generally means minimizing the total order picking time. This includes the travel time incurred in picking an order which corresponds to the length of a picking tour from start to finish [5]. Improving the replenishment activity usually means reducing the number of storage refreshing tasks.

Determining the proper storage locations for potentially thousands of products is one major task. One of the main factors that affect the storage assignment is the order picking method. Chan and Chan [6] present a simulation study of a real case regarding the storage assignment of a manual-pick and multi-level rack warehouse. They concluded that the key to effective implementation of a storage assignment system is to match the type of warehouse storage system to the variety of items in the customer order. Also, the use of key performance indicators should clearly reflect the needs of the warehouse. Strack and Pochetand [7] propose a tactical model that did not include the order picking activity for the warehouse management system (WMS) which integrates several phases of the decision process: replenishment, allocation of products and assignment of products to storage locations. Jinxiang et al. [8] offer a detailed survey of the research on warehouse design, performance evaluation, practical case studies, and computational support tools. They suggest that avenues for important contributions for future research include studies describing validated or applied design models, and practical case studies that demonstrate the potential benefits of applying academic research results to real problems. The LCOPRM presented in this paper intends to fulfill these latter suggestions.

Based on a real problem, this study presents an applied design model illustrated by a practical case study. A case study is a linear and iterative process that includes the following stages: plan, design, prepare, collect, analysis and share [9]. We acknowledge that, on one hand, the case study method lacks quantitative rigor which makes it difficult to replicate results. However, on the other hand, we concur with Rowley [10] that the large amount of data accrued from case study research enables a certain amount of generalization to emerge. The authors believe that the experience from case studies performed in the industry provides proof of concept, demonstrating the successful application of such academic research results to real problems.

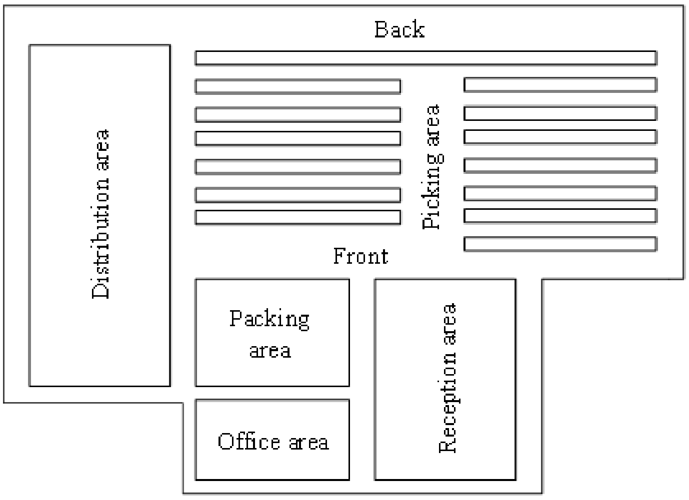

Figure 1 - Logistics center layout

Large-scale logistics centers usually use a WMS in order to manage all relevant information. The WMS is used to track inventory, receive and place items in complex automated storage, and retrieve items by order pickers [11]. The WMS thus produces a large amount of historical data on customer orders that can be retrieved, reclaimed, analyzed, and presented to manufacturing decision makers [12]. A customer’s order may consist of one or more items, each with a different requirement. While fulfilling the customer’s order, sometimes a warehouse splits the customer order into smaller pick lists (e.g., a list of separate items for picking, each with different quantities). Each pick list is handed out to an order picker. The order picker goes to the relevant locations in the warehouse to pick the correct quantity of each article using material handling equipment, such as a forklift. Wave picking or batch picking [5] enables customer orders to be picked simultaneously by a group of order pickers [13]. Usually, a single customer order is attached to a specific order wave which handles several customer orders and the route is given to the order picker using a pick list [14]. A pick list that minimizes order picking time is used for optimum planning. Several time-efficient heuristic methods to determine the route order in a single-block warehouse have proven effective [4]: (1) S-shape method – if there is at least one pick in the aisle the picker will enter and cross the aisle in the block (see Figure 2). (2) Return method – pickers enter and leave each aisle from the same entrance. Notice that in methods (1) and (2) aisles without picks are not entered. (3) Midpoint method – divides all the aisles into two areas; each area is routed by the return method. (4) Largest gap method – if the gap between adjacent picks is large, the picker performs a return route from both ends of the aisle. (5) Combined method – aisles with picks are either entered and crossed or entered and exited at the same point.

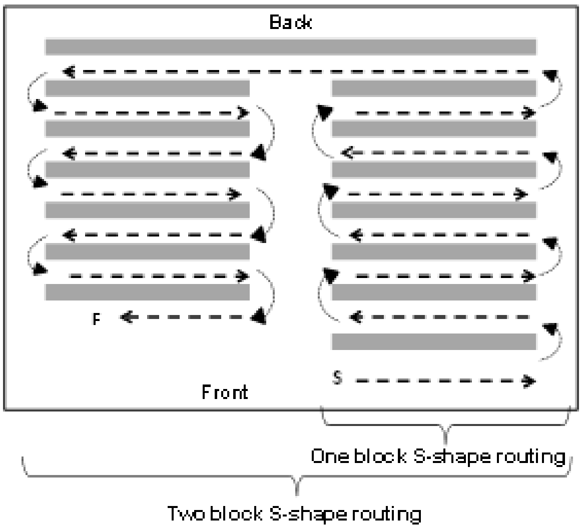

Figure 2 - S-shape method

This paper presents a monolithic model for improving picking orders and replenishment activities in a large-scale logistics center for an office equipment retail company. The company logistics center covers 11,000 square meters (see the layout in Figure 1) and employs over 200 employees. The company provides office equipment to educational institutions and businesses. There are over 4,000 items stored at 4,800 separate picking locations throughout the warehouse. The order is not split into smaller pick lists. Instead, each picker collects several orders related to a specific picking wave. The company warehouse is divided into two blocks. The picker's route begins at the front of one block of the warehouse and goes to the back using the S-shape method (Figure 2); the order picker then returns through the other block from the back to the front using the same method. The left block contains six rows, and the right block contains seven rows. There is also one single long row at the rear of the warehouse. The aisle width between two adjacent rows allows two forklifts to work simultaneously. There are several types of storage spaces in the warehouse, each with different dimensions: (a) "Varitz" – the smallest rack in the warehouse measuring 50 × 40 × 50 [cm^3] length × width × height respectively can contain several packages or a few units of a specific item; (b) "Rack" – measuring 100 × 60 × 100 [cm^3] can contain several boxes; (c) "Flow Rack" – has a sloping shelf with wheels measuring 240×40×50 [cm^3] and can contain several boxes; (d) "Small" – can contain half a pallet and measures 120 × 80 × 100 [cm^3]; (e) "FullPlt" – measuring 120 × 80 × 200 [cm^3] can contain up to one pallet; (f) "Double Deep" (DD) – measuring 240 × 80× 200 [cm^3] can contain up to two pallets. The long row at the rear of the warehouse is of type DD only. As part of its policy to adopt a lean management methodology and to strive for continual improvement of the logistic process [15], the company acquired a WMS called "Warehouse Expert" which is the flagship product in Made4Net's company supply chain suite. Recently the office equipment retail company also built an advanced warehouse with new equipment and technologies. Despite these improvements manpower costs remained unchanged (mainly due to the employment of workers in multiple shifts). The value stream mapping (VSM) tool [16] helped to identify where to increase cost reduction efforts throughout the logistics center (i.e., by targeting the main sources of waste). In the current state, the picker passes through all the aisles to pick one order (see Figure 3). Also, in many cases items are stored in inappropriate locations. For instance, an item with a high sales volume per month was located in a small location type, which requires many replenishment tasks. By identifying the sources of waste in the warehouse the next stage is to suggest ways to reduce picking distances and the number of replenishment tasks.

The remainder of this paper is organized as follows. Section 2 presents the LCOPRM that improves the performance of the replenishment and order picking activities. This section also provides an analysis of the process data. The implementation results are presented in Section 3. Section 4 summarizes the findings and suggests some future directions.

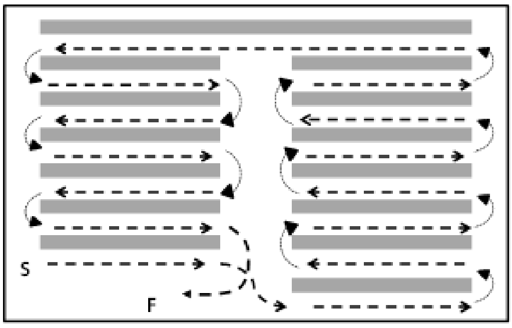

Figure 3 - Initial picking activity

2. The LCOPRM policy

The focus of the current research is to develop a method for performing order picking and replenishment activities. Our method uses the class-based storage (CBS) policy. Whereas in the literature the outcomes of using this policy have been shown by simulation only (see [17-19]), in this study the results are illustrated by the problem solved in a real logistics center. Prior literature discusses many different methods for assigning products to shelf spaces to optimize order picking such as the cube-per-order index [5] or storage assignment based on item demand correlation [20]. The LCOPRM developed in this research is divided into five stages (see Figure 4). The first stage of the method uses the ABC method, a special case of the CBS policy [21]. It analyzes warehouse processing data and classifies items according to their relative number of picking tasks into three groups, A, B, and C. The Pareto principle on which the ABC method is based, states that 80% of the number of picking tasks comes from 20% of the items [22]. The second stage uses a heuristic to define the best location type in the warehouse for each item, taking into account the item's sales volume. The third stage includes selecting the best alternative for dividing the warehouse into areas, and the fourth stage selects a route strategy for the pickers. The final stage includes implementing the previous stages and measuring the difference from the current state. From time to time the logistics center practitioners should return to the first stage.

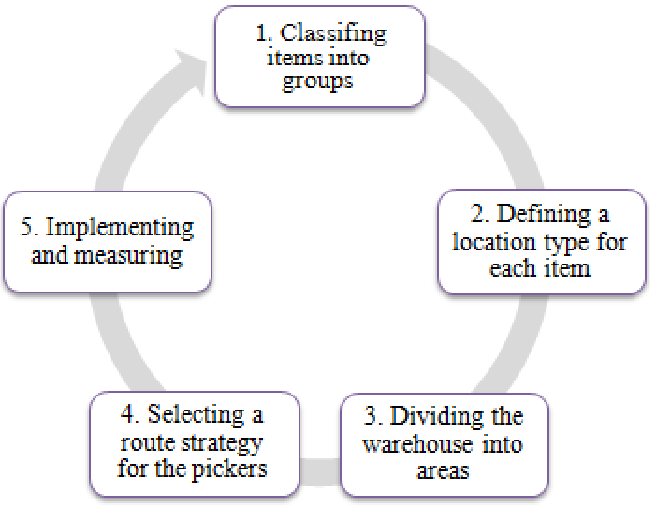

Figure 4 - A LCOPRM

2.1. Classifying items

In this paper the ABC method presupposes that the causes of waste are the items, and the effects are the number of picking activities such that: 20% of the causes are responsible for 80% of the effects, 30% of the causes are responsible for 15% of the effects, and 50% of the causes are responsible for 5% of the effects [21]. During the study, the items and the picking activities were classified using the same policy. In Figure 5 every field (drawn as one rectangle) indicates a picking location. A gray rectangle indicates an item of category A at that location. Since items of category A (which are the most common in the collection of orders) were scattered throughout the warehouse area, the picker had to travel a long distance to complete a single picking wave.

To examine the categories of items (A, B or C) in an average customer order, the orders and their waves during an ordinary work day were checked. The purpose was to see if a pattern repeats itself in each wave. 24 different waves on different dates were examined. Each wave contained an average of 296 orders and 1,261 different items (totaling 30,264 items). Each order had an average of 4.4 items and the picker had to pass through an average of 10.3 rows per wave (Table 1). With a confidence level of 95%, the distribution of the customer orders in each wave contained the following averages: 39.2% orders with only A-category items, 11.8% with only C-category items, and 49% with items from two or three categories (see **Error! Reference source not found.**). To reduce the distance needed to travel per wave, the authors recommended grouping all items of category A together in one area, and all items of category C in another area of the warehouse (leaving all items of category B in yet another area).

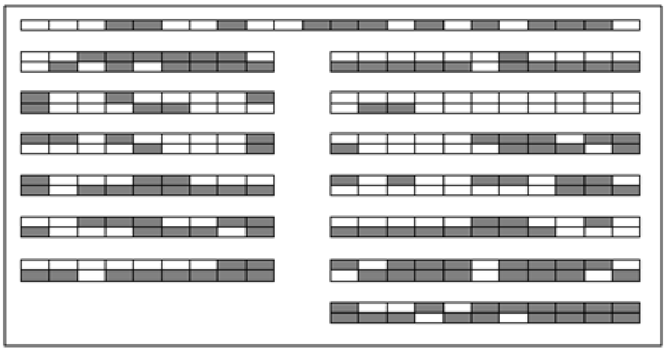

Figure 5 - Current location of A-items

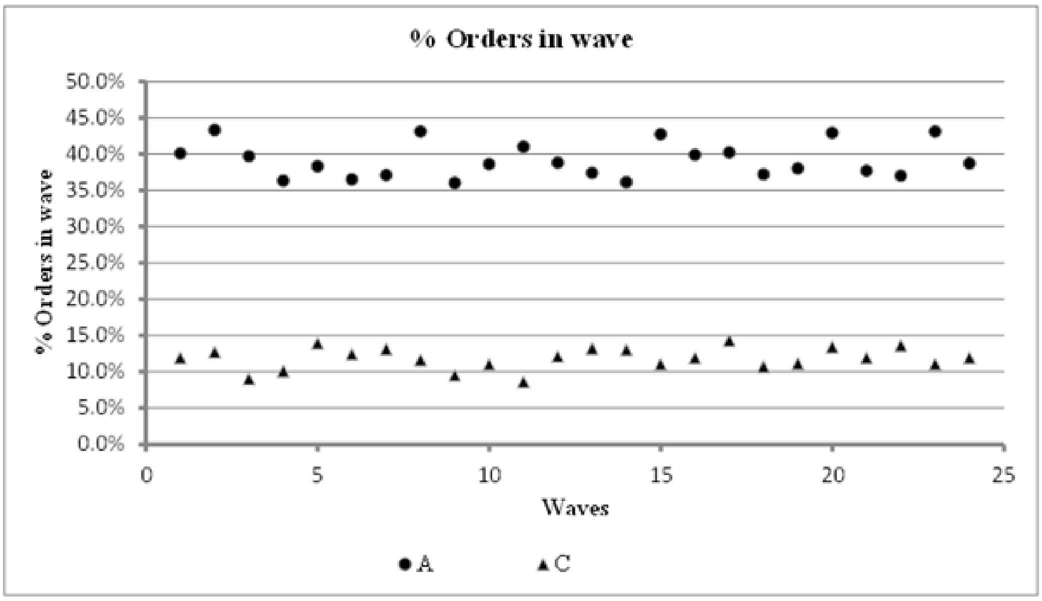

Figure 6 - % orders with only A or only C items

Wave detailes		# of			Average			% orders with items of	
Name	Date	orders	items	rows	items per order	rows per order	rows per items	class A	class C
W2304124	24/04/2012	216	884	2008	4.1	9.3	2.3	40.1	11.9
W1503124	14/03/2012	174	888	1983	5.1	11.4	2.2	43.3	12.7
W2102124	20/02/2012	230	1144	2492	5	10.8	2.2	39.7	9.0
W1405121	10/05/2012	284	1080	2672	3.8	9.4	2.5	36.3	10.1
W0506121	04/06/2012	428	1778	5036	4.2	11.8	2.8	38.3	13.9
W1804122	17/04/2012	323	1453	3807	4.5	11.8	2.6	36.5	12.4
W2205123	21/05/2012	301	1236	2924	4.1	9.7	2.4	37.1	13.1
W0706121	06/06/2012	448	1430	4062	3.2	9.1	2.8	43.1	11.6
W0405122	02/05/2012	401	1381	4031	3.4	10.1	2.9	36.0	9.5
W2806121	26/06/2012	282	996	2382	3.5	8.4	2.4	38.6	11.0
W2507121	22/07/2012	375	1372	3508	3.7	9.4	2.6	41.0	8.6
W1507122	11/07/2012	161	784	2720	4.9	16.9	3.5	38.8	12.1
W04121201	04/12/2012	359	1344	3715	3.7	10.3	2.8	37.4	13.2
W0612121	06/12/2012	365	1447	4134	4	11.3	2.9	36.1	13.0
W2312124	23/12/2012	266	1402	2876	5.3	10.8	2.1	42.7	11.0
W1003124	10/03/2012	236	1404	2048	5.9	8.7	1.5	39.9	11.9
W1102124	11/02/2012	226	1358	3430	6	15.2	2.5	40.2	14.3
W1405121	14/05/2012	345	1398	2349	4.1	6.8	1.7	37.2	10.7
W0506121	05/06/2012	276	1351	2208	4.9	8	1.6	38.0	11.1
W1804122	18/04/2012	223	1271	2180	5.7	9.8	1.7	42.9	13.4
W1706121	17/06/2012	252	946	2106	3.8	8.4	2.2	37.7	11.9
W2405122	24/05/2012	331	1218	3781	3.7	11.4	3.1	37.0	13.6
W1806121	18/06/2012	309	1435	3073	4.6	9.9	2.1	43.1	11.0
W0507121	05/07/2012	286	1263	2336	4.4	8.2	1.8	38.7	11.9
Average		296	1261	2994	4.4	10.3	2.4	39.2	11.8
Standard Deviation		76	232	849	0.8	2.2	3.7	2.4	1.5

Table 1- Wave samples

2.2. A heuristic approach to find a suitable picking location for each item

Every item in the warehouse has a unique picking location. The responsibilities of the replenishment department are: (1) Selecting the proper location for each item according to demand. As demand for an item increases or decreases, an appropriate picking location is selected according to its sales volume; and (2) ensuring that the inventory at each picking location is sufficient for the next wave. Usually, this means moving items from the long-term storage zone to the picking locations.

Prior to the current research, there was no organized method for determining the locations of items. Placement was based solely on the experience and logic of the employees in the replenishment department. In this study, a heuristic approach is proposed to set a location type for each item in order to minimize the number of replenishment tasks. Due to the warehouse capacity limitations, some of the items would be stored in a location type that can contain up to four weeks of demand. Let X_n $\forall\, n = 1 \ldots 6$ represent the capacity of location type n (i.e., the location volume in $[\text{cm}]^3$), such that for n equals to: 1 = Varitz, 2 = Rack, 3 = FR, 4 = Small, 5 = FullPlt and 6 = DD. Let $j = 2, 3$ or 4 weeks, and represent the amount of inventory periods in weeks. Let $Y_j = 4/j$, be the inventory turnover (i.e., number of replenishment tasks) per month, such that: $Y_2 = 4/2 = 2$, $Y_3 = 4/3 = 1.25$ and $Y_4 = 4/4 = 1$. Also, let Z_i be the sales volume of item i per month in $[\text{cm}]^3$. For instance, if the average month sale quantity of an eraser is 200 units per month and the dimensions of one unit is $4.3 \times 1.9 \times 1.3\ [cm^3]$, then the eraser sales volume, $Z_i = 4.3 \times 1.9 \times 1.3 \times 200 = 2{,}124\ [\text{cm}]^3/\text{month}$. The heuristic is divided into two phases: (1) calculating for item i and inventory period j the appropriate picking location type (denoted by x_{ij}), and (2) selecting for item i the best location type, out of the options given in phase 1. The calculation of phase 1 is presented in the pseudo-code below. The sales volume is multiplied with a safety factor of 125%. For example, Table 2 shows the calculation output for six items. The table contains the following data: item SKU, category of the item according to the previous classification stage, and location type for each inventory period.

```
Begin
    Initialization: x_ij = 0 ∀i = 1 ... the last item, j = 2,3,4 ;
    For i = 1 to the last item Do
        For j = 2 to 4 do
            If (Z_i · 1.25/X_n) ≤ Y_j Than x_ij = n;
            Else n = n + 1;
        End For
    End For
End
```

#	SKU	Category	Location type for period		
			4 weeks	3 weeks	2 weeks
1	1112354	A	DD	DD	FullPlt
2	3478356	A	DD	DD	FullPlt
3	1994839	C	DD	Rack	Varitz
4	4914264	B	FullPlt	FullPlt	Small
5	3068756	C	Small	FR	FR
6	5436817	B	Rack	Rack	Varitz
⋮					
4000	1232344	A	Rack	Rack	Rack

Table 2 - The output of the optimization formula

In phase 2, a location type is selected for each item out of the options given in phase 1 to fully utilize the picking locations in the warehouse. Since the problem is constrained by a predefined number of locations of each volume type, it belongs to the family of Knapsack problems [23]. Previously, it was decided that all items of each category (A, B and C) would be located together in the same warehouse area. Hence, to simplify the Knapsack problem at hand, the number of combinations was reduced from $4{,}000^3$ to 3^3 by selecting an inventory turnover (i.e., inventory periods in weeks) for each category of items rather than for each individual item. Table 3 presents the inventory period (in weeks) per category: (1) the total number of replenishment tasks per month, and (2) the utilization of the picking locations in the warehouse. The utilization percentage of the location types is calculated as $\sum_i X_{x_{ij}}$ divided by the total volume of the locations in the warehouse. The number of replenishment tasks per month is calculated as $\sum_i \left(Z_i / X_{x_{ij}}\right)$. The utilization should be less or equal to 100%. If this is not the case, the combination is denoted as unfeasible, and the number of replenishment tasks should not be calculated. Note that, combination number 17 in Table 3 achieves the minimal number of replenishment tasks per month, namely choosing inventory period three, two and four weeks for categories A, B, and C respectively. Based on the results of phase 2 one can choose a location type for each item according to its category and the calculation performed in phase 1 (see for example the cells marked in gray in Table 4). The item with an SKU = 1112354, for instance, will be located in location type DD, since the inventory period for items of type A is three weeks.

Combination #	A	B	C	Replenishment tasks (# per month)	Picking locations utilization (%)
	Inventory period in weeks				
1	4	3	3	-	Unfeasible
2	4	2	4		
3	4	3	4		
4	4	4	2		
5	4	4	3		
6	3	4	4		
7	3	4	2		
8	3	4	3		
9	4	4	4		
10	4	2	2	2549	100
11	4	2	3	-	Unfeasible
12	3	3	2		
13	3	2	2	2676	93
14	3	2	3	2498	96
15	3	3	2	2436	100
16	3	3	3	-	Unfeasible
17	3	2	4	2430	99
18	3	3	4	-	Unfeasible
19	2	3	3	2647	89
20	2	2	4	2845	85
21	2	3	4	2608	92
22	2	4	2	2713	90
23	2	4	3	2536	94
24	2	4	4	2468	96
25	2	2	2	3090	79
26	2	2	3	2913	83
27	2	3	2	2851	86

Table 3 - # of replenishment tasks for each combination

#	SKU	Category	Location type for period		
			4 weeks	3 weeks	2 weeks
1	1112354	A	DD	DD	FullPlt
2	3478356	A	DD	DD	FullPlt
3	1994839	C	DD	Rack	Varitz
4	4914264	B	FullPlt	FullPlt	Small
5	3068756	C	Small	FR	FR
6	5436817	B	Rack	Rack	Varitz
⋮					
4000	1232344	A	Rack	Rack	Rack

Table 4 - Selected location type per item

2.3. Dividing the warehouse into three areas

The third stage of the LCOPRM requires dividing the warehouse into three areas and implementing a picking route strategy. A number of alternatives for dividing the warehouse into three Pareto areas were examined. Each alternative must meet the following principles of the company: (a) for picking simplification each aisle must contain only one location type, and every area must contain all the location types; (b) minimize traffic jams in the warehouse (i.e., one forklift should not block the passage of another forklift). Note that as the area contains longer aisles (i.e., more than one block), the probability of traffic jams increases; and (c) the last long row at the rear of the warehouse must belong to items of category A, since many of these items require the DD location type. Out of multiple options that can be considered for dividing the warehouse into three areas, the four most practical options for the company under study are presented in Figure 7. All options satisfy principle (c). Options 1 and 4 do not satisfy principles (b) and (a). According to factory data, option 2 does not satisfy principle (a). Therefore, option number 3 is preferred, since it satisfies all of the company's constraints.

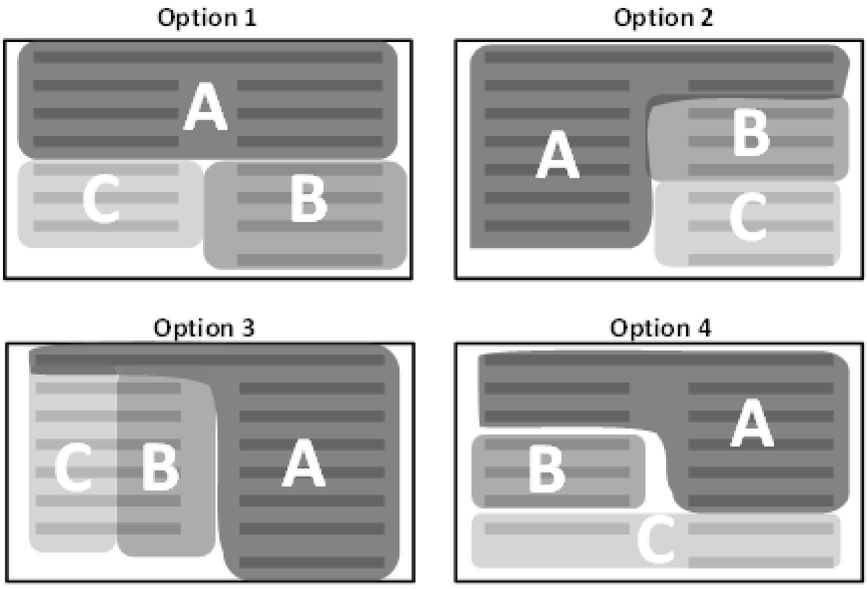

Figure 7 - Pareto alternatives

2.4. Selecting a route strategy for the pickers

In the fourth stage the route strategy for the pickers is selected. The picking route strategy refers to the path that the pickers follow while collecting items. Each time a picker finishes collecting one order of a wave, the same picker starts a new order in the same wave. The picker receives a list of items from the WMS sorted according to the worker’s route. The route begins from the starting point (noted as S in Figure 8) and ends at the finishing point (noted as F in Figure 8), moving from one aisle to the next. To determine the minimal route, one should consider that 39.2% of customer orders are only from category A, and 11.8% of the customer orders are only from category C. Therefore, for 51% of the orders the picking takes place on only one block of the warehouse and on two blocks for the other orders. Alternative 3 in Figure 8 describes a two or one S-shape (according to the order), and is the only one that enables picking from one block if needed.

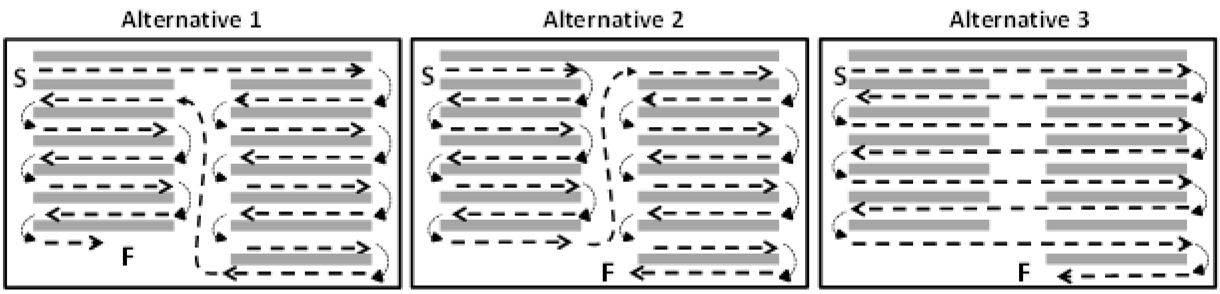

Figure 8 - Alternatives of picking route

3. Results

This section presents the implementation results of the stages described in Sections 2.1-2.4 (i.e., the fifth stage of the LCOPRM). The status of the warehouse before and after implementation of the new method is displayed using performance measures that include the distance a picker travels while picking a customer order and the average number of replenishment tasks per month. Before implementing the new method, the picker passed 15 aisles (seven on one block and eight on the other block) to pick a single order (see Figure 3). After implementation, on average the picker passed through $0.392 \times 9 + 0.118 \times 7 + 0.49 \times 15 = 11.7$ aisles/orders (as illustrated by the picking route example in **Error! Reference source not found.**), an improvement of 22%.

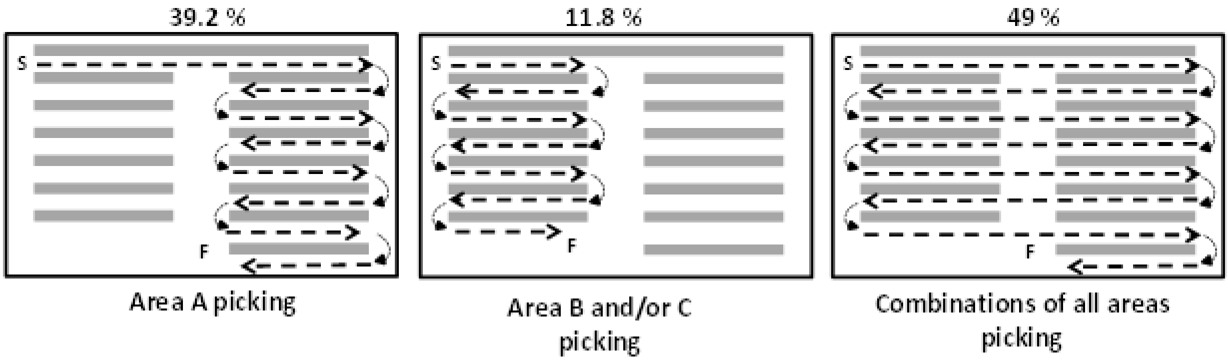

Figure 9 - Average picking route distribution

At the initial state (period *a*) the average number of replenishment tasks per month was 4,853. After implementing the LCOPRM (period *b*), the average number of replenishment tasks per month was 2,964, an improvement of 38.747%. Sorting and placing items according to the ABC method required changes of the location types for many items and no change for others. The items were divided into three classes: (1) high demand items that were located in a small location type and were therefore moved to a larger location type; (2) low demand items that were located in a large location type and were therefore moved to a smaller location type; and (3) items whose demand corresponded with their location type and remained in place. Changes in the average item replenishment tasks per month were examined statistically (with $\alpha = 0.05$) before (μ_a) and after (μ_b) implementation of the new method by a paired sample t-test (F1). The null hypothesis states that there was no influence of the LCOPRM on the number of replenishment tasks per month (H_0), and the alternative hypothesis (H_1) states that μ_a and μ_b are not the same.

$$H_0: \mu_a - \mu_b = 0 \qquad H_1: \mu_a - \mu_b \neq 0 \qquad \text{(F1)}$$

Table 5 displays the results of the statistical tests. For the items in classes 1 and 2 the null hypothesis was rejected, and for the items in class 3 the null hypothesis was accepted. Hence, for items in class 1, the number of replenishment tasks decreased by 65.165% between period *a* and period *b*. For the items in class 2 the number of replenishment tasks increased by 215.663%, and for the items in class 3 there was no change. For the total number of items the null hypothesis was rejected, and therefore the total replenishment tasks per month decreased by 38.747%.

Class		Average # of replenishment per month	Average # of replenishment per month per item	Standard Deviation	P-Value	T-Value	T-Critical
1	period *a*	3438.497	2.753	7.64	9.9886E-19	8.952	1.647
	period *b*	1197.791	0.959	2.2			
	difference	2240.706	1.794	5.44			
2	period *a*	166.105	0.209	0.33	4.654E-105	27.198	1.648
	period *b*	524.199	0.66	0.44			
	difference	-358.094	-0.451	-0.11			
3	period *a*	1237.773	0.47	0.664	0.438	0.157	1.646
	period *b*	1244.092	0.472	0.663			
	difference	-6.3192	-0.002	0.001			
Total	period *a*	4842.375	1.036	4.118	5.9581E-13	7.13	1.645
	period *b*	2966.082	0.634	1.271			
	difference	1876.293	0.402	2.847			

Table 5 - Paired sample t–test

Error! Reference source not found. (i) illustrates the distribution of replenishment tasks for items in classes 1, 2 and 3. For 60% of the items in class 1 the number of replenishment tasks decreased, for 35% of the items there was no change and for 5% of the items the number of replenishment tasks increased. The explanation for the fact that the number of replenishment tasks for 40% of the items in class 1 did not decrease may be that in the time elapsed from the category classifications to the actual relocation of items the classification was no longer fit. Hence, we reason that during this time lapse the category of the item changed according to product demand. **Error! Reference source not found.** (ii) illustrates that for 95% of the items in class 2 the number of replenishment tasks increased and for the other 5% they decreased between periods *a* and *b*. **Error! Reference source not found.** (iii) shows that for most of the items whose demand corresponded with their location type (class 3) the total number of replenishment tasks remained unchanged.

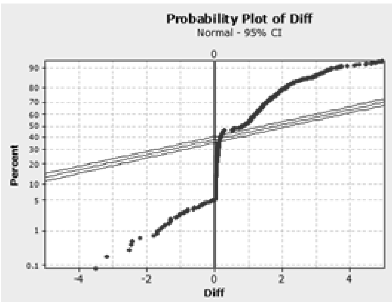

Figure 10 (i) – Class 1 probability plot

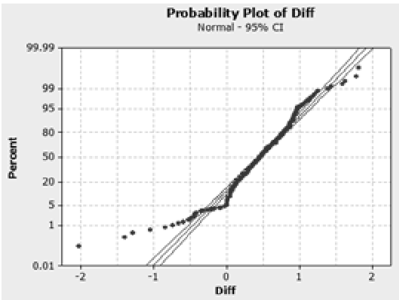

Figure 10 (ii) – Class 2 probability plot

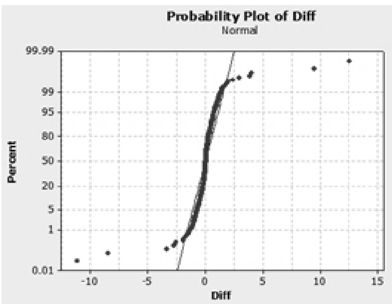

Figure 10 (iii) – Class 3 probability plot

Figure 10 – Probability plots

4. Summary

Order picking is typically one of the most time-consuming activities and a large contributor to operational costs in warehouses [24]. Clearly, improving order picking is an important way to save costs in logistics centers. Furthermore, because many customers tend to order late and expect quick delivery, warehouses must improve the efficiency of their order picking [25]. The LCOPRM proposed in this paper presents a practical approach that companies can implement swiftly. The method minimizes two major sources of waste in the warehouse: the number of replenishment tasks (a decrease of 38.747%), and the distance a picker travels while collecting customer orders (22% shorter). This is accomplished by selecting a suitable location type for each item according to its sales volume. Disregarding the correspondence between the item sale volume and its location type generates unnecessary work, excessive manpower, spending overtime, and failure to comply with customer service agreements. Also, the method proposed in this paper divides the warehouse picking area into smaller areas according to the Pareto principle and selects a route strategy for the pickers. Preserving separate areas assures the reduction of the route needed to collect customer orders.

Further research may be conducted to find different combinations of approaches for each stage of the LCOPRM for different industries and illustrating results via case studies. Those case studies might form the basis for proper implementation of the LCOPRM by logistics centers professionals. Since the project is based on the CBS policy, and the volume sale of each item may change due to seasonal factors and product turnover as shown in Figure 10, the classification of items to category may change over time. Therefore, to conserve the results of this work the authors recommend addressing this issue. Since the classification of thousands of items to their category types and the adjustment of items to their appropriate locations requires considerable work, this research suggests the development of a specific LCOPRM module for the company WMS. The module suggested must send an alert when an item is located in an area that does not correspond with its current volume sale; the model must also recommend the transfer of the item to the appropriate area and location type in the warehouse.

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