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Cross aisle placement in order picking operations

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ABSTRACT

Order picking operations need to efficiently process order in today's competitive environment. Previous research generally assumed on even placement of the cross aisles. This research examines the placement of cross aisles in order picking operations and the use of various storage policies. While previous research has examined cross aisles and storage policies, this research looks at them simultaneously. The results showed no difference between even and uneven placement of cross aisles and that within-aisle storage is better than across-aisle and random storage.

KEYWORDS: Distribution Warehousing, Order Picking, Cross Aisles, Storage Policies, Supply Chain

INTRODUCTION

Order picking is a process of retrieving items or stock-keeping units (SKU) from warehouse storage locations to satisfy customer orders and this process plays an important part in reducing warehousing and supply chain costs. Order picking constitutes 50 - 75% of the total operating costs for a typical warehouse (Bozer et al, 2010, Coyle et al, 2003). Today's warehouse managers are under a lot of pressure due to the global competition and supply chain integration initiatives to decrease order picking time in order to increase the throughput rate and lower operating costs of their operations (Frazelle, 2002).

Previous order picking research generally focuses on one of three main operating policies to improve the performance of the system: picking, routing, storage, and layout. Picking policies involve assigning items or orders to picking tours and include strict-order, batching, and zoning. Routing policies determine the route of a picker for a picking tour and range from simple heuristics to optimal procedures. Storage policies assign SKUs to storage locations. Commonly used storage policies are random storage and class-based storage where SKUs are sorted by ABC analysis into storage classes. Layout considerations are the orientation and position of picking and cross aisles.

The focus of this research is to examine the placement of a cross aisles. Previous research generally assumes an equal spacing of cross aisles, but have ignored whether unequal placement might reduce picker travel even more. In addition, the authors will evaluate the performance of class-based storage policies relative to random storage with both equally spaced and unequally spaced cross aisles in a manual picking warehouse where order size varies from only a few SKUs to many SKUs.

LITERATURE REVIEW

Order picking has been the topic of much research over the past several decades. The primary focus for most of this research has been identifying more effective picking, storage, routing, and layout policies.

Picking

Picking policies determine which SKUs are placed on a pick list and subsequently retrieved from their storage locations by a single picker. Strict-order picking is a common policy where pickers complete a tour through the warehouse to pick all SKUs for a single order. This policy is often preferred because it is easily implemented and order integrity is always maintained. Combining several orders into batches is an alternative policy that has been shown to reduce total picking time significantly (Gibson & Sharp, 1992; Rosenwein, 1996; De Koster et al, 1999; Petersen, 2000). Zone picking is another policy that divides the warehouse into zones and allows pickers to retrieve SKUs from within a single zone. Some firms have combined batching and zoning into “wave” picking where each picker is responsible for SKUs in their zone for numerous orders. The benefit for these types of policies become apparent as the size of the warehouse increases, but zone picking requires secondary operations to consolidate orders from the different zones (Petersen, 2000). For this study we will assume that orders are batched and that no picking zones are used.

Storage

Storage policies assign SKUs to storage locations. The most common policy is random storage where SKUs are assigned randomly throughout the warehouse. It is easy to administer and may ease picker congestion. Volume-based storage (VBS) policies where SKUs with the most requests or pick activity are assigned to locations near the Pick-up/Drop-off (P/D) point based on their picking volume (Jarvis & McDowell, 1991; Caron et al, 1998; Petersen & Schmenner, 1999; Jane, 2000). They are generally most effective at improving performance, but are information intensive and far more difficult to administer than a random storage policy (Petersen & Schmenner, 1999). Similar to the VBS policy, CBS ranks SKUs according to pick activity then partitions the SKUs into several storage classes and randomly assigned warehouse locations within their respective storage class area. The storage class containing the highest volume SKUs is located nearest to the P/D point. The impetus of a CBS policy is to capitalize on the logic of the VBS policy, while eliminating the considerable administrative overhead (Larson et al, 1997). Class-based storage with as few as three storage classes provides nearly the same savings as volume-based storage in an automated storage and retrieval systems (Hausman et al, 1976; Rosenblatt & Eynan, 1989; Eynan & Rosenblatt, 1994) and in manual warehouses while requiring less data processing (Petersen et al, 2004). For this study class-based storage will be used.

Routing

Routing policies determine the picking sequence of SKUs on the pick list. Using simple heuristics or optimal procedures, the goal of routing policies is to minimize the distance traveled by the picker. Optimal procedures offer the best solution, but may result in confusing routes (Ratliff & Rosenthal, 1983). Heuristics often yield near-optimal solutions while being easy to use (Hall, 1993; Petersen, 1997). Traversal routing, which is widely used in many warehouses because of its simplicity, provides good results when the pick density per picking aisle is large.

When using a traversal policy, pickers must completely traverse the entire aisle once it is entered. The combined heuristic combines traversal and return routes to further reduce picker travel to produce near-optimal solutions (De Koster & Van der Poort, 1998; Petersen, 1999; Roodbergen & De Koster, 2001a). Vaughan and Petersen (1999) developed a dynamic programming shortest path routing method to minimize the total picking distance in warehouses with multiple cross aisles. For this study we will use the combined heuristic as it has the advantage of near optimal results and requires less computational effort.

Layout

The layout of the warehouse has been considered as a factor affecting the order picking efficiency. Several issues have been researched from the alignment of the picking aisles with respect to the P/D point, the location of the P/D point, and the overall shape has also been taken into consideration as factors effecting order picking efficiency (Bassan et al, 1980; Petersen, 2002; Gue & Meller, 2009; Pohl et al, 2011). Adding cross aisles to a warehouse layout allows greater flexibility in order picking routing and therefore provides shorter order picking travel distances (Ben-Mahmud, 1987; Vaughan & Petersen, 1999; Caron et al, 2000; Roodbergen & De Koster, 2001b).

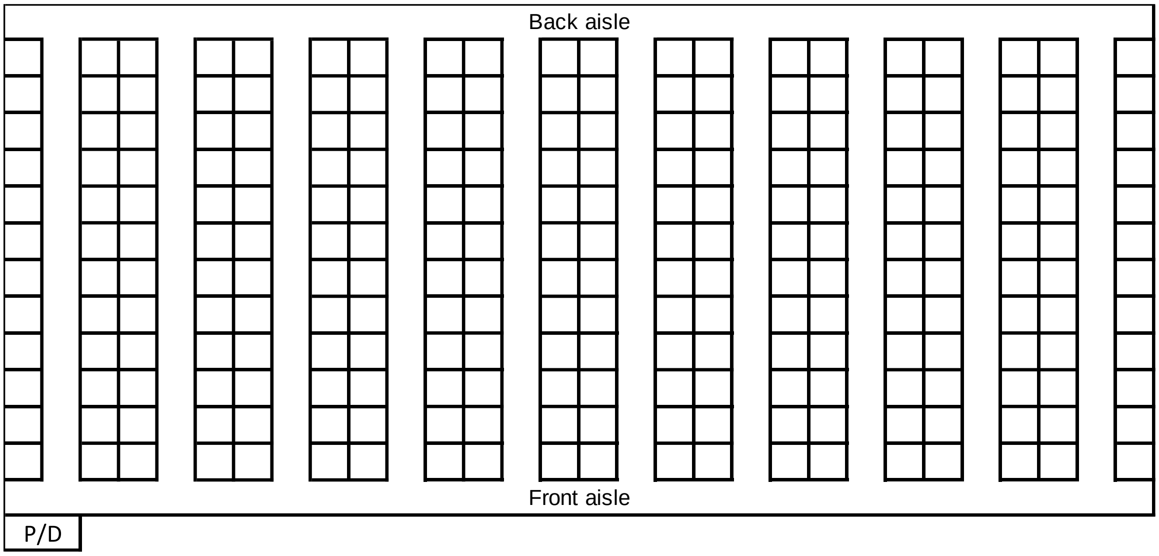
There has been research on the use of class-based storage and the placement of cross aisles. Rao and Adil (2013) investigate class based storage and the number of aisles for a variety of pick list sizes, however, their work considers only a return routing policy via the use of a center cross aisle. Berglund & Batta (2012) show analytical results that unequal cross aisles are superior to equally-spaced cross aisles. However, their results assume a center P/D point and use pick list sizes of only two to ten SKUs. In this paper, the authors use a corner P/D point, a combined routing heuristic, and use larger pick list sizes as many firms process batch orders and/or have larger orders.

This study addresses several of these outstanding items. First, this study evaluates the even and uneven placement of cross aisles with a corner P/D point in a manual order picking environment that uses bin shelving. Second, this research compares class-based storage to random storage in a warehouse with no or two cross aisles. Lastly, this research examines the effect of order pick size on the performance of cross aisle placement and storage polices.

EXPERIMENTAL DESIGN

The warehouse layout examined has ten picking aisles with front and back cross aisles. The pick-up and drop-off (P/D) point is located in the left side of the front aisle as shown in Figure 1. This model replicates a manual-picking environment where picking carts are used to transport the picked SKUs. The picking aisles are two-sided and are wide enough to allow two-way travel of picking carts. Picking can be done from both sides of the aisle without a significant change in position. The capacity of the bin shelving is 1,200 SKUs and each SKU is assigned to a single storage location. There are twelve bin facings on each side of the picking aisles and there are five storage slots per bin facing. Strict-order/batch picking is used where a picker departs the P/D point to retrieve SKUs on the pick list and transports the SKUs back to the P/D point for order consolidation, packaging, and shipment. The picking carts are designed in a manner that maintains order integrity while minimizing downstream sorting. This is commonly referred to as sort-while-pick picking. Total travel distance is collected for each simulation trial. Travel distance consists of travel along the front and back aisles and travel within the picking aisles. Because the aisle width is relatively small, we assume the operator can reach shelves on either side of the aisle without an increase in travel distance. Therefore, the composite routing heuristic is used for this experiment. This routing procedure can achieve close to optimal results when the pick density is high (Petersen & Schmenner, 1999; Petersen & Aase, 2004).

Figure 1: Basic layout



When using a class-based storage policy, SKUs are ranked according to their total volume. The ranked SKU list is partitioned into several classes, where the high volume SKUs are placed in one class and the lower volume SKUs are placed in additional classes. SKUs are then randomly assigned to storage locations within their respective class storage area (Petersen et al, 2004). For this experiment, a class partition strategy of 20/30/50 was utilized representing the ABC classes. One design parameter that a warehouse manager must select when using class-based storage policies entails the selection of the class partition strategy. Partition strategy of 20-30-50 are used for the three class system in this experiment (Petersen et al, 2004).

The other factor to consider is the number of SKUs to be picked in a picking tour. Petersen and Schmenner (1999) showed that pick list size affects the performance of storage and routing policies. Therefore, three levels of pick list sizes are considered: 5 SKUs, 15 SKUs, and 25 SKUs. Results for additional pick list sizes can be easily extrapolated from the results presented.

The purpose of this research is to examine effects of a combination of three of the factors that affect order picking efficiency is shown in the experimental design (Table 1). For the cross aisle placement Figure 2 shows an even cross aisle placement of four facings between each cross aisle. Figure 3 shows an uneven cross aisle placement of three facings between the first three cross aisles and six facings between the last two cross aisles. Figures 4 and 5 show across-aisle and within-aisle storage policies.

Table 1: Experimental design

Level	Layout	Storage Policy	Pick List Size (SKUs)
1	Basic (B)	Random (R)	5
2	Even Cross aisles (E)	Within-aisle (W)	15
3	Uneven Cross aisles (U)	Across-aisle (A)	25

There are 30 replications or pick lists generated for each pick list size. For a given pick list, SKUs are randomly generated using an 80/20 SKU demand distribution where the top 20% of the SKUs account for 80% of the demand by volume. The performance is measured by calculating the total travel distance for the order picker to complete an order. C coding has been used to simulate the warehouse model with the each of the different factors individually.

Figure 2: Even cross-aisle placement layout

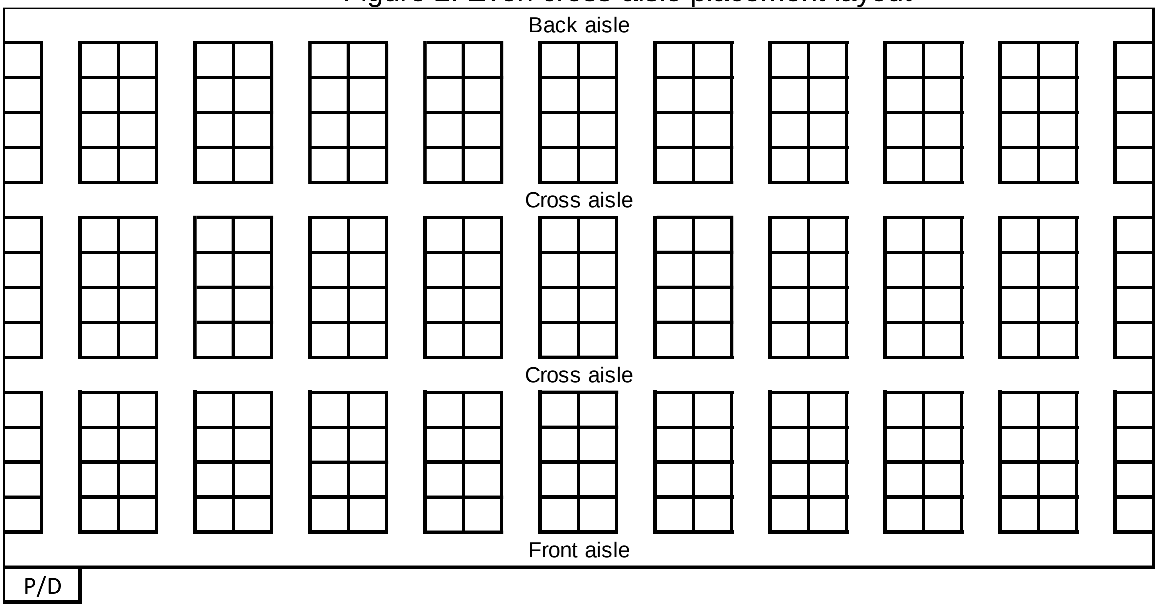


Figure 3: Uneven cross-aisle placement layout

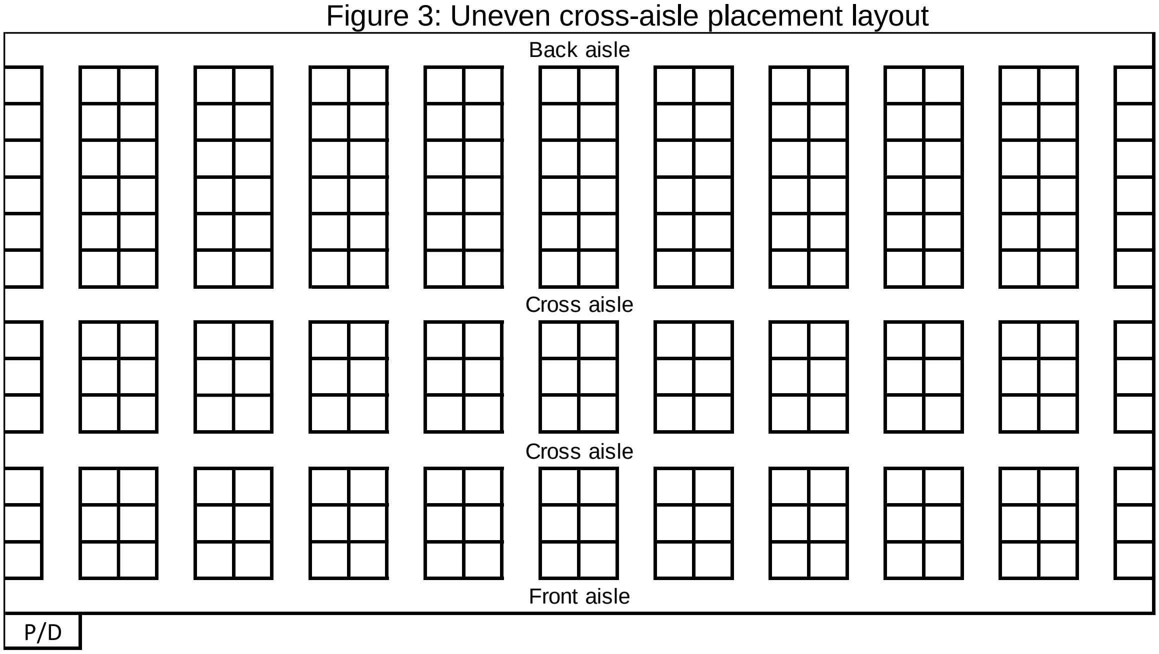


Figure 4: Across-aisle layout

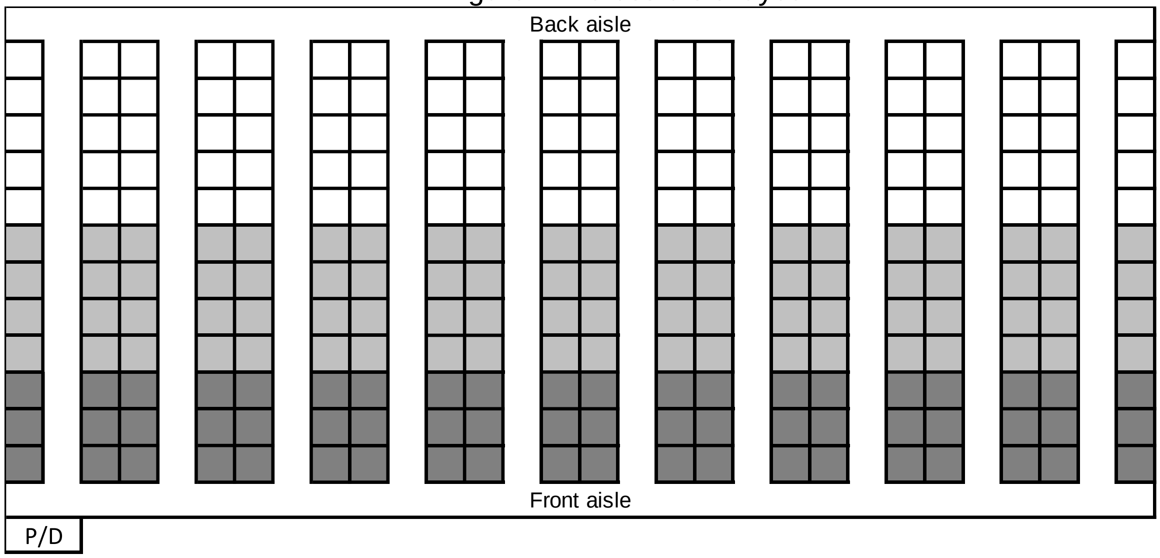
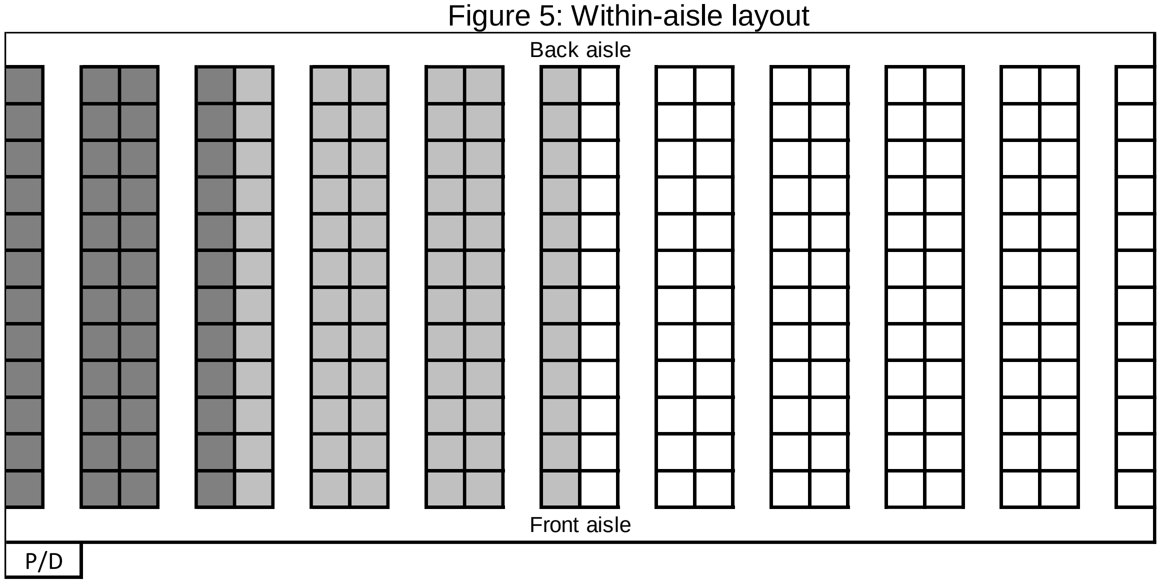


Figure 5: Within-aisle layout



RESEARCH HYPOTHESES

The authors generated the following research hypotheses based on previous research.

Hypothesis 1

H_A: Layout with even cross aisles ≠ Layout with uneven cross aisles

Hypothesis 2

H_A: Layout with even cross aisles < Basic layout

Hypothesis 3

H_A: Layout with uneven cross aisles < Basic layout

Hypothesis 4

H_A: Layout with across-aisle storage < Layout with random storage

Hypothesis 5

H_A: Layout with within-aisle storage < Layout with random storage

Hypothesis 6

H_A: Layout with within-aisle storage < Layout with across-aisle storage

RESULTS

The results of the simulation experiment are presented in Table 2. A full-factorial analysis of variance (ANOVA) is in Table 3. The model F-value of 93.20 implies the model is significant and is statistically significance for all factors (A = Layout, B = Storage, C = SKUs) and interactions.

Table 2: Simulation results (picker travel in feet)

	Basic Layout			Even Cross Aisles			Uneven Cross Aisles		
	Random Storage	Across-aisle Storage	Within-aisle Storage	Random Storage	Across-aisle Storage	Within-aisle Storage	Random Storage	Across-aisle Storage	Within-aisle Storage
5	346.2	338.9	192.8	270.1	208.7	153.9	272.0	206.2	155.4
15	537.3	532.5	274.8	476.8	332.1	258.3	478.1	328.8	258.4
25	598.0	594.5	316.4	600.4	391.4	309.4	600.1	391.3	308.6
Overall	493.8	488.7	261.3	449.1	310.8	240.6	450.1	308.7	240.8

Table 3: Analysis of variance

Source	Sum of squares	df	Mean square	F value	Prob > F
Model	525,069	14	37,505	93.2	< 0.0001
A	39,626	2	19,813	49.2	< 0.0001
B	212,549	2	106,275	264.1	< 0.0001
C	223,780	2	111,890	278.0	< 0.0001
AB	29,150	4	7,288	18.1	< 0.0001
BC	19,963	4	4,991	12.4	0.0003
Residual	4,829	12	402		
Total	529,898	26			

The research hypothesis tests results are shown in Table 4.

Hypothesis 1

Even and uneven cross aisles perform statistically the same regardless of storage policy. This result requires further investigation as is there no difference or does it depend on the placement of uneven cross aisles.

Hypothesis 2

Layouts with even cross aisles perform statistically better than the Basic Layouts. This follows the results of Vaughan and Petersen (1999) that cross aisles can reduce picker travel.

Hypothesis 3

Layouts with Uneven cross aisles statistically perform better than the Basic Layouts. A cross aisle regardless of its location does reduce picker travel. Again this result requires further investigation that is beyond the scope of this paper.

Hypothesis 4

Across-aisle storage performs statistically better than Random storage except in the absence of cross aisles. Previous research has found that Across-aisle storage reduces picker travel compared to random storage but most of that research used optimal routing (Petersen et al, 2004). In this paper using traversal routing each aisle must be completely traversed unless there is a cross aisle that allows access to the next picking aisle.

Hypothesis 5

Within-aisle storage performs statistically better than random storage. This goes in line with the findings of (Petersen & Schmenner, 1999; Petersen & Aase, 2004).

Hypothesis 6

Within-aisle storage performs statistically better than across-aisle storage. This goes in line with the findings of (Petersen et al, 2004).

Table 4: Hypothesis test results

Hypothesis		***t***	***p*-value**
	ER≠UR	-0.048	0.9621
1	EA≠UA	0.176	0.8606
	EW≠UW	-0.025	0.9803
	ER<BR	2.433	0.0080
2	EA<BA	12.634	<0.0001
	EW<BW	2.366	0.0095
	UR<BR	2.390	0.0089
3	UA<BA	12.734	<0.0001
	UW<BW	2.359	0.00967
	BA<BR	0.320	0.3746
4	EA<ER	8.361	<0.0001
	UA<UR	8.562	<0.0001
	BW<BR	18.437	<0.0001
5	EW<ER	13.039	<0.0001
	UW<UR	13.188	<0.0001
	BW<BA	17.814	<0.0001
6	EW<EA	6.626	<0.0001
	UW<UA	6.413	<0.0001

From the results it has also been observed that a basic layout with within-aisle storage is better than layouts with even or uneven cross aisles with random or across-aisle storage. Table 5 shows that the results of some post-hoc t-tests show that within-aisle storage in a basic layout is statistically better than the addition of cross aisles with random or across-aisle storage.

Table 5: Post-hoc test results

Hypothesis	***t***	***p*-value**
BW<ER	12.163	<0.0001
BW<EA	5.079	<0.0001
BW<UR	12.294	<0.0001
BW<UA	4.838	<0.0001
BW<BR	18.437	<0.0001
BW<BA	17.814	<0.0001

CONCLUSIONS

This paper evaluated cross-aisle placement in a manual warehouse with class-based storage. The results show that even and uneven cross-aisle placement does not statistically differ and that the addition of cross aisles did significantly reduce picker travel as had been shown in previous research. As in warehouses without cross aisles, within-aisle storage results in significantly less picker travel than across-aisle and random storage in a warehouse with cross aisles. In fact, within-aisle storage resulted in less picker travel than the addition of cross aisles in a random or across-aisle storage warehouse. All of these results held for small, medium, and large pick list sizes.

There are drawbacks to class-based storage in that in can result in increased picker congestion which may offset some of the picker time savings. Also the use of cross aisles could increase the possibility of picker accidents if pickers are not careful at cross and picking aisle intersections. A limitation of this research is that only one uneven cross-aisle placement strategy was considered, but this provides an avenue for future research to evaluate other uneven cross-aisle placement strategies in manual warehouses.

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