AN APPLICATION OF DISCRETE EVENT SIMULATION ON ORDER PICKING STRATEGIES: A CASE STUDY OF FOOTWEAR WAREHOUSES

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ABSTRACT

A footwear business is one of highly competitive markets. Footwear businesses must continuously improve three main key performance measures namely quality, cost and lead time. The case study is one of footwear businesses in Thailand. As customer demands are fragmented, the company needs to offer different products to serve customers' satisfaction. Customer orders are then small quantities, but contain serveral different product types. As a result, picking activities in its warehouse are becoming more difficult especially for sport shoes, fashion shoes and sandals. While individual order picking strategy was utilized, it caused long lead time in its picking process. Its delivery performance cannot be achieved. Discrete event simulation modeling using ARENA was conducted to investigate the performance of one order picking, batch picking and zone picking. It was found that the best alternative is zone picking with 4 orders per batch. The picking time can be shortened about 15%.

INTRODUCTION

It has been recognized that quality, cost and time are major key performance indicators for almost all companies need to keep tracking and improving. Shortening throughput and delivery lead times can offer a competitive advantage as quick responses to customer demand uncertainties or requirements are inevitable. Warehouses provide an important link in supply chains, where products can be temporarily stored and retrieving products from storage can be managed regarding customer orders (Petersen 2002). To manage warehouses, there are main warehouse activities to consider such as receiving, put-away, storage, order picking, packing, loading stock counting, value-adding services (Richards 2014). The cost of order picking is estimated to be about 55% of the total warehouse cost as order picking has been considered as the most labour-intensive and costly activity which almost all warehouses (De Koster et al. 2007). Order picking is then a retrieving process of products or items from warehouse storage locations to fulfil customer orders (Petersen et al. 2004). To improve the efficiency of order picking process can shorten supply chain lead time and reduce warehousing and supply chain costs.

To improve order picking efficiency, order picking strategies are being utilized. Discrete picking or individual picking is where a picker is assigned to pick all the items in a single order for a pick-tour. In batch picking, many orders are grouped or batched together and a picker picks all the items for a given batch. Zone picking assigns each picker to a specific zone or zones and is responsible for picking the items in that zones (Parikh and Meller 2008). Warehouses should select and apply those strategies to fit with their nature of products and demand patterns.

In view of order picking process, a footwear company in Thailand has explored its order picking process. The objective of this study is to investigate possibilities of applying picking strategies to its order picking process and evaluate its benefits based on time and labor utilization. The next section provides the background of the case study, followed by a survey of the related literature. Research methodology and results are proposed. Finally, conclusions and suggestions are described.

BACKGROUND OF THE CASE STUDY

The case study, called "ABC", is a Thai footwear company and has its own brand products. As customer demands are fragmented and fast-changing, ABC has offered a variety of product to customers that are school shoes, fashion shoes, sport shoes and sandals. To serve its customers, ABC has its own warehouse to store and replenish the products to their customers that are modern trades, wholesalers, retailers and also e-commerce customers. The warehouse is equipped with racks, forklifts, barcoding, wifi, warehouse management system (WMS), and safety systems.

Warehouse Activity

The warehouse activities include purchase order entry, goods receiving, put-away, picking, invoicing, checking, dispatch, reverse logistics, replenishment and stock count. Purchase order entry is dealing with supply planning and purchase order placing to its factory. Goods receiving process starts from preparing goods

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receipt schedule, preparing storage space, checking products received against the goods receipt schedule and record in WMS. Put-away activity is to move the products received to the locations assigned with using barcoding and handhelds. Picking process includes picking list formulation, picking assignment and picking travelling and moving to marshalling lanes. According to the limitation of WMS, the only picking strategy available is individual order picking.

After products are picked, labelling the products and issuing invoices are the next main activities. Checking process is conducted to insure that the products picked and invoice are correct. Dispatching process is to move the products into trucks or vans and passing the ownership to third-partly logistics. Reverse logistics is to received returned products from customers and invoice deduction. Replenishment is to move products from reserved area to picking face area. Stock counting is to count all products in the warehouse. It was found that inventory accuracy of the warehouse is 97%. In the warehouse, there are eleven staff. Five staffs are mainly working to manage all information and planning such as purchasing planning, invoice issuing and other documenting processing. Six staffs are assigned to be pickers.

Warehouse layout

The warehouse area is 4,800 square meters and consists of ten racks, namely A to J. Each rack contains five levels and the ground floor level is assigned to be pick face areas. From the second floor level to the fifth floor level are specified as reserved areas. The put-away process is performed by random location generated by WMS.

Demand chateristics

There are 13,355 active stock keeping units (SKUs) in the warehouse. About 80% SKUs is school shoes which has its 2 high seasons during summer vacation and October vacation. For two high seasons, the movement of products are almost full-pallet picking. Individual order picking is appropriate to handle during high season periods. During off-peak season, customer orders are small quantities, but serveral different product types. The effect of individual picking process caused fatigue in pickers as they had to walk very long distance. It was difficult to balance work-load. In addition, rush orders cannot be finished on time. It was then needed to improve picking process in off-peak season.

LITERATURE REVIEW

Richards (2014) classified order picking strategies three categories that are picker to goods, goods to picker and automated picking. The majority of warehouses continue operating with picker-to-goods operations. Picker to goods strategy consists of individual order picking, cluster picking, batch picking, zone picking and wave picking. Individual order picking or discrete order picking is a picker takes one order and travels through the warehouse on foot or using forklifts to collect items until the whole order is completed. Peterson and Aase (2004) also noted that discrete order picking is often preferable because it is easy to implement and order integrity is always maintained.

Cluster picking, a picker can have many orders at a time and travels around the warehouse to pick items into individual compartments on their trolleys or pick carts. In other words, picking and sorting can be done at the same time by using trolleys or pick carts that provide individual compartments. Cluster picking can extend to use with pick-to-light technology as well (Richards 2014).

Batch picking is similar to cluster picking as operators pick many orders at the same time, but orders are consolidated or batched into a picking list. After picking all items will be sorted or allocated into each customer order. The batch picking is then pick-and-sort (Richards 2014). Peterson and Aase (2004) described batch picking as combining several orders into batches. First-come-first-served (FCFS) batching can combine or consolidate orders as they arrive until the maximum batch size has been reached. This can be a way that order batching can be conducted. Parikh and Meller (2008) provided insights of batch picking. Batch picking can be classified into two categories that are pick-and-sort and sort-while-picked. Batch picking with pick-and-sort method can increase pick-rate of pickers because sorting is not a part of picking and decrease chances of workload-imbalance. At the same time, probability of blocking can increase as a result, pick tours can be long. Batch picking with sort-while-pick method can decrease chances of workload-imbalance and does not require a sorting system, while pick-rate can decrease as sorting is a part of picking process. In addition, probability of blocking can be increased.

Zone picking is where picking is defined by areas in the warehouse. Pickers are assigned to pick from a particular zone or zones. Orders can be picked at the same time within the zones and the items picked will be sorted or allocated according to each customer order later (Richards 2014). Parikh and Meller (2008) described zone picking with sequential or progressive method is to pick one order at a time and in one zone at a time. In contrast, zone picking with simultaneous or synchronized method is to pick all items regarding batched orders are picked at the same time from all the zones and then orders are sorted. Zone picking with progressive can increase a pick-rate of pickers as pick-tours are short and do not need a sort system. It can eliminate blocking problems, but it can increase chances of workload-imbalance. Zone picking with synchronized method can increase a pick-rate of pickers as pick-tours are short and eliminate blocking as well, but it requires a sorting system and may result in increasing workload-imbalance.

Wave picking is that orders are consolidated and released at particular times to associate them with vehicle departures or replenishment cycles (Richards 2014). Peterson and Aase (2004) noted that wave picking is the combination of batching and zoning into ‘‘wave’’ picking where a picker is responsible for SKUs in their zone for several orders. The benefit of these policies become evidently when the size of the warehouse increases, but zone picking needs sorting operations to consolidate orders from the different zones. Marchet et al. (2011) noted that the pick-and-sort system is to pick a number of each single item from the batching of multiple orders (wave) and place them at the sorting area. As a result of order accumulations, the same item will be picked at the same time. It can reduce the number of different locations in pick-tours or so called ‘overlapping effect’. The pick-and-sort system is then based on picking waves. The period of time in which a groups of orders is picked in one picking area before moving to the next area such as sorting area.

To improve order picking process, companies require to apply order picking strategies and techniques that are appropriate to the nature of product, the size of order and the quantity of items. Studies have been conducted to improve order picking process. Tang and Chew (1997) conducted a simulation study to review the effect of batch size on tardiness. They noted that smaller batch size could reduce the average delay time when compared to one order picking with unlimited resources. Petersen (2002) studied the effects of picking zone configuration on picker distances. The storage size of the picking zone, picking policies and the number items of pick list were included. As an example, batch zone operations normally have large pick lists per zone and would perform well with zone configuration having one or two aisles. However, volume-based storage affects less travel distances than random storage for all zone configurations. Peterson and Aase (2004) conducted intensive simulation modelling to investigate several picking, storage, and routing policies. Several sensitivity analyses are constructed to evaluate the effect of order size, warehouse shape, location of pick-up/drop-off point, and demand distribution on performance. Batching of orders can offer the greatest savings especially when smaller order sizes are usual. Rim and Park (2008) proposed a linear programing model to conduct border batching with subject to minimize the order fill rate. Then, a simulation study was conducted to investigate the performance of LP and FCFS on order batching. Although the FCFS fule has an advantage of smoothing the picking load and reducing the number of pickers, the proposed LP performs better in terms of the order fill rate by 12.7%. It was pointed out that the order fill rate creases when the number of orders or items increases. Planning order picking can increase the order fill rate. As order batching methods can significantly affect the order fill rate and customer service levels, Henn and Schmid (2013) applied metaheuristics in order batching and sequencing. The proposed metaheuristics can improve the total tardiness of a given set of customer orders by 46%.

To improve and measure picking process, not only picking efficiency or productivity have been investigated, but the cost model has been proposed. Parikh and Meller (2008) developed a cost model to estimate the cost of batch picking and zone picking. The cost model included the cost of pickers, equipment, imbalance, sorting system, and packers. It was found that workload-imbalance is greater in zone picking comparing to batch picking. workload-imbalance is more important when the order sizes increase, item distribution is not likely to be uniform, and the number of waves increases. Marchet et al. (2011) introduced an analytical model to estimate the picking efficiency regarding wavelength. Simulation modelling has been conducted to validate the analytical model. A case study of book distributors was presented to describe how the model can be applied to estimate picking efficiency based on the size of the wave and to determine the trade-off between picking efficiency and sorting cost. The results show that the number of waves has a significant effect on the pick-and-sort system. The number of picking waves per day should not be too small that is a long wavelength per pick, as it can crease the sorting costs and the picking efficiency could not be balanced. The appropriate number of waves cannot be generalizable and it must be determined based on the operating environment. The further study may propose an extension to include considerations in terms of peak versus non-peak activity levels, and a generalization through the modelling of the costs and activities of the pick-and-sort systems.

Muanul picking and automated picking has been studied by Lee et al. (2015). They conducted the experiments to evaluate the performance of manual order picking and pick-to-light picking or digital supported manual order picking that can help pickers to seek for locations and amount of the items on the storage or shelves. It was found that the pick-to-light technology can reduce both mean and standard deviation values of picking time.

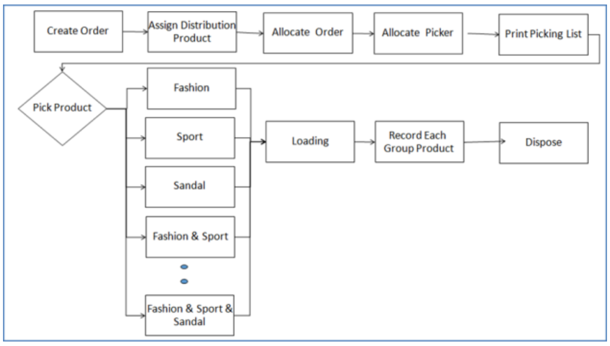
It can be seen that many authors are interested in exploring tools or techniques to improve picking processes with regarding some key performance measures such as time, tardiness, distance, workload and cost. However, the picking configurations proposed cannot be generalized for all circumstances. This research is then constructed from a real life situation and concerns both time and workload. The techniques investigated are batching and zoneing as they can be implemented in the case study without no adding too much cost comparing to automated picking systems.

Simulation modelling can be a tool to investigate the effects of order picking. The next part is research methodology used to conduct this research.

RESEARCH METHODOLOGY

Discrete event simulation, ARENA, is applied as a tool to study this research. Off-peak sales seasonal is selected to study its effect on picking process as customer orders are small and high-variety. The current picking process includes receiving customer orders, allocating orders, assigning picker, printing pick list, picking travel (individual order picking), and dispatching. From the current process, it can be written as a flow chart shown in figure 1. The results from the current situation are used as a base line to compare with other alternatives.

Batch picking and zone picking are studied based on one wave per day. FCFS is the technique applied to batch or group customer orders. Batch and zone picking proceses will start from order receiving, allocating orders (batching orders), assigning pickers based on batch picking and zone picking, printing picking list, pick tours, sorting and dispatching.



Figures 1: The Current Picking Process

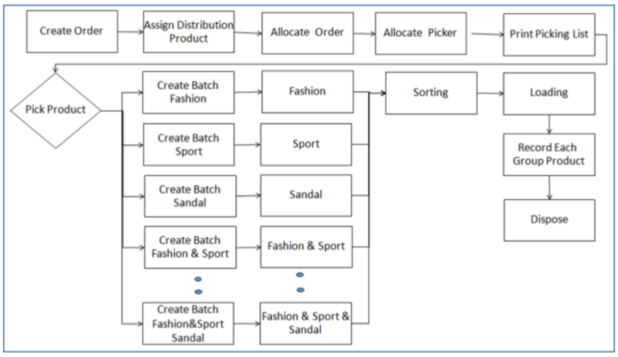


Figure 2 : Batch and Zone Picking Processes

Scenarios proposed

To investigate the effects of picking strategies, three main scenarios are proposed. The current situation, discrete order picking is investigated. Batch and zone picking are examined based on 2 to 6 orders grouping. Two main performance measures are evaluated that are staff utilization and lead time.

Table 1 : Scenarios Proposed

Picking policy	Order grouping					Performance measures
Discrete order	none					Staff utilization and time
Batch picking	2	3	4	5	6	
Zone picking	2	3	4	5	6	

Verification and validation

Daily operations for 180 days were collected to use in the simulation program conducted. Every input datum is fitted with theoretical probability distribution by using input analyzer module in ARENA Verfication has been conducted for each module in order to assure that the simulation program can perform as required. Five key variables are receiving orders, allocating orders, printing picking list, order picking and dispatching used to validate with real life performances. It was found that the five key performances obtained by simulation are not significantly different from the actual performances as shown in table 2.

Table 2 : Output Validation

	Actual (min.)		Simulation (min.)	
	Average	Half Width	Average	Half Width
Checking orders	9	0.45	8.33	0.02
Printing picking list	1	0.05	0.999	0
Order picking Fashion	6.98	0.27	7.95	0.09
Sandals	18	0.9	17.13	0.23
Sport	16	0.8	15.67	0.54
Dispatching	3	0.08	3.00	0.01

To identify run length and run replication, equation 1 was used to identify number of replications (Kelton et al. 2007)

$$n \cong n_0 \frac{h_0^2}{h^2} \qquad (1)$$

The expected number of replications is represented by n. The desired half width is h and n_0 represents the number of replications for the pilot run. The half width obtained from the pilot run is h_0. The desired half width picking time is less than 5 minutes. The simulation is conducted based on terminating system as the case study starts working from waiting for customer orders and finishing its work once all customer orders received have been dispatched. The number of replications is twenty.

Althoug batch picking and zone picking never utilized with the case study, a time and motion study was conducted to obtain some processing time variables to apply in batch picking and zone picking simulations. The next part is results from simulation runs.

RESULTS

Current situation

The simulation on current situation that is using individual picking has been conducted. It was found that the longest lead time in the process studied is allocating orders. The allocating order activity takes about 68.57 minutes per order. During allocating order, there is waiting time in process as well called 'cut off order'. The main reason of cut off order is to consolidate all orders to dispatch. For picking activtities, seven types of picking has been found that are to pick within product family, combining product families. Picking three different product families can result in 37.56 minutes per order, as shown in table 3. In addition, total process time for each order type has been collected and shown in table 4. It can be seen that increasing product variety leads to increasing total process time per order. Applying individual order picking results in low staff utilizations. Table 5 shows staff utilizations and all pickers are found to be busy no more than 60% of their total time.

Batch picking

Batch picking has been explored by batching or grouping two orders per batch until six orders per batch. When batch picking is performed, total process time per order can be reduced. Picking time is shortened, but allocating order time is increased. Allocating order time increases because batching order is conducted by manual as existing WMS does not support this activity.

Table 3 : Currrent Situation Results

Process	Time per one order (min.)	
	Average	Half Width
Checking orders	8.33	0.02
Allocating orders	68.57	2.47
Printing picking list	0.999	0
Order picking		
Fashion	7.95	0.09
Sandals	17.13	0.23
Sport	15.60	0.54
Fashion & Sandals	23.51	1.3
Fashion & Sport	19.50	2.28
Sport & Sandals	30.44	2.56
Fashion & Sport & Sandals	37.56	3.18
Dispatching	3.00	0.01

Moreover, increasing number of batching will directly increase waiting time to group or batch customer orders. Only a three-order-batch picking is selected to illustrate in more details. Table 6 shows total process time per order of a three-order-batch picking policy. Not only cam the total time be reduced, the utilization of staff can be reduced as well, as shown in table 7.

Table 4: Current Total Process Time per Order

Types	Average (min.)	Half width (min.)
Fashion	88.86	2.59
Sandals	98.04	2.73
Sport	96.51	3.04
Fashion & Sandals	104.42	3.8
Fashion & Sport	100.41	4.78
Sport & Sandals	111.34	5.06
Fashion & Sport & Sandals	118.47	5.68

Table 5 : Current Staff Utilization

Staff	Utilization (%)	
	Average	Half width
Picker 1	53	0.01
Picker 2	54	0.01
Picker 3	57	0.01
Picker 4	52	0.01
Picker 5	55	0.01
Picker 6	50	0.01

From the experiments, it was found that a four-order bach can give the shortest process time as a six-order batch results in higher total process time due to increasing of allocating order time and sorting time, as shown in table 8. Moreover, when many orders are grouped, walking distances can be reduced and it can be shown in terms of staff utilization shown in table 9.

Table 6 : A Three-Order-Batch Picking Time per Order

Types	Average (min.)	Half width (min.)
Fashion	80.48	2.38
Sandals	86.13	2.67
Sport	103.10	5.93
Fashion & Sandals	98.23	8.01
Fashion & Sport	81.35	5.84
Sport & Sandals	79.95	5.37
Fashion & Sport & Sandals	94.93	3.28

Table 7 : A Three-Order-Batch Staff Utilization

Staff	Utilization (%)	
	Average	Half width
Picker 1	17	0.01
Picker 2	17	0.01
Picker 3	18	0.01
Picker 4	18	0.01
Picker 5	16	0.01
Picker 6	16	0.01

Table 8 : Average Total Process Time of Batch Picking

Types	Average total process time (min/order)				
	As-Is	Batch picking			
		2	3	4	6
Fashion	88.86	81.63	80.48	79.84	84.75
Sandals	98.04	88.14	86.13	84.87	89.06
Sport	96.51	99.03	103.10	101.38	100.03
Fashion & Sandals	104.42	107.76	98.23	83.10	82.33
Fashion & Sport	100.41	97.20	81.35	78.31	0.00
Sport & Sandals	111.34	92.66	79.95	76.82	0.00
Average	99.93	94.40	88.20	84.05	59.36

Table 9 : Staff Utilization of Batch Picking

Types	Utilization (%)				
	As-Is	Batch picking			
		2	3	4	6
Picker 1	53	27	17	13	9
Picker 2	54	27	17	14	9
Picker 3	57	27	18	12	8
Picker 4	52	26	18	11	6
Picker 5	55	26	16	11	6
Picker 6	50	26	16	12	7

Zone picking

Zone picking simulation has been conducted by batching or grouping two orders per batch up to six orders per batch. The results are similar to those of batch picking. When having more orders grouping, picking time can be shortened, but allocating order time and sorting time will increase. It was found that a four-order batching can offer the shortest process time as shown on table 10. However, zone picking can give a better result in term of staff utilization as three staff can be reduced. Table 11 shows utilization of staff when zone picking is applied.

CONCLUSION

From the results, it can be concluded that individual picking strategy cannot perform well due to the nature of orders that are small and contain a variety of products. Zone picking and batch picking with using FCFS strategy to group orders are found to be preferable. The both two strategies can shorten total process time, but zone picking performs better than batch picking in terms of staff utilization. Therefore, zone picking can be appropriately implemented during low season. To get a better result, other batching techniques should be investigated as they may shorten picking time. Batch sizing has significantly affected mean order throuput time. From our investigation, batching up to four orders is recommended.

Table 10 : Average Total Process Time of Zone Picking

Types	Average total process time (min/order)				
	As-Is	Zone picking (Batch size)			
		2	3	4	6
Fashion	88.86	80.62	80.26	79.13	84.19
Sandals	98.041	86.92	85.85	84.32	88.52
Sport	96.51	101.22	102.83	102.20	99.63
Fashion & Sandals	104.42	110.25	99.72	85.35	81.63
Fashion & Sport	100.41	97.01	86.12	77.79	0.00
Sport & Sandals	111.34	97.13	81.95	76.69	0.00
Average	99.93	95.52	89.45	84.24	58.99

Table 11 : Staff Utilization of Batch Picking

Types	Utilization (%)				
	As-Is	Zone picking (Batch size)			
		2	3	4	6
Picker 1	53	27	21	17	23
Picker 2	54	6	4	2	2
Picker 3	57	26	20	15	21
Picker 4	52	0	0	0	0
Picker 5	55	0	0	0	0
Picker 6	50	0	0	0	0

Moreover, if WMS would need to modify to support zone picking, simulation modelling should be conducted to cover high season periods to investigate whether or not individual order picking can perform better than zone picking. To modify WMS, order allocating and sorting activites will be added.

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