2018

Managing the Order Picking Process in for Click and Collect in Grocery Stores

Dale T. Masel
Ohio University, masel@ohio.edu

Akhilesh Mesa
Ohio University, am049113@ohio.edu

Managing the Order Picking Process in for Click and Collect in Grocery Stores

Dale T. Masel
Dept. of Industrial and Systems Engineering
Ohio University
Athens, Ohio USA
masel@ohio.edu

Akhilesh Mesa
Dept. of Industrial and Systems Engineering
Ohio University
Athens, Ohio USA
am049113@ohio.edu

***Abstract*—Many grocery stores offering a service called "Click and Collect," where customers can submit an order online and pick up the order at the store or have it delivered. To offer this service in an efficient way while still meeting customer expectations, stores can adapt methods used in warehouse order picking. One strategy is the method used to group the orders into batches as they are received. We have examined two strategies for batching: order-based batching and time-based batching. From testing these two approaches, time-based batching produces a slightly lower average picking time, but order-based batching has orders ready for the customers sooner. Store managers can choose the approach that better meets their store's objective.**

***Keywords*—click and collect, order picking, batching, retail**

I. Introduction

A recent trend in the grocery business is offering a service called Click and Collect (C&C), which allows customers to place an order online and collect it at the store. The customers who utilize this service no longer need to go inside the store to pick their products because the store workers are picking the products for the customers. In a survey conducted by Nielsen Holdings (a global e-commerce information, data, and measurement company), 57% of the respondents are willing to use an online platform to order their groceries.

When a customer order arrives, a worker travels to the shelves to pick the products to fulfill the customer order, a procedure which is similar to order picking in a warehouse. Hence, warehouse order fulfillment policies could be used to increase the efficiency of C&C service.

One order picking policy that C&C could adopt is order batching. For a system where orders to be picked arrive throughout the day, there are two order batching strategies: order-based batching (OBB) and time-based batching (TBB). In OBB, a batch is formed after a fixed number of orders arrive. For example, if the desired batch size is three, once three orders arrive, a worker starts picking the products for all three orders. In TBB, orders that arrive within a certain time interval are batched together. For example, if the time interval is 30 minutes, the orders which arrive within 30 minutes of the previous batch being dispatched are grouped into a batch. The objective of this research is to evaluate how the average pick time for an order and the average ready time is affected by the batching strategy.

II. Literature Review

Since the C&C service is relatively new to the industry, to the best of our knowledge there is no previous research conducted on methods for managing C&C order fulfilment. Most of the research is focused on the customer analysis and information technology. The customer analysis research is mainly focused on the purchasing attitude of the customer [1]-[10]. Research on information technology is concentrated on how to use existing technology to improve the customer experience for their online grocery shopping [11]-[15].

The characteristics of order fulfillment in C&C are similar to warehouse order picking procedures. Therefore, previous research related to routing and batching strategies in a warehouse can be considered for application to C&C order fulfillment.

Chew and Tang [16] analyzed order batching and storage allocation strategies in an order picking system for a rectangular warehouse. The order picking system was modeled as a queueing model and considered OBB policy. Travel time analysis was performed for random and class-based storage assignment. Their results show that the picking and sorting time of the batch increases with an increase in the size of the batch. For the same batch size, class-based storage assignment offers better savings in picking time than random storage.

Xu et al. [17] proposed a travel time model and analyzed how the throughput time of customer order is affected by variable time window batching. For this analysis, it was assumed that the products are stored based on random storage policy. Their results show that the expected throughput time of the customer order can be achieved when there are a small number of picking aisles and lower expected inter-arrival times. Their results also suggest that the length of the picking aisles does not have much effect on the customer throughput time.

Petersen [18] presented five order picking routing policies: traversal, return, midpoint, largest gap and composite. In the traversal strategy, a worker enters from one end of the aisle, travels to the storage locations to retrieve products, then leaves from the other end of the same aisle. Traversal is best suited for grocery stores because of the narrow aisles. Except for traversal, all the other policies require the worker to turn around within the aisle. Petersen's results suggest that the optimal routing has shorter routes, but it does not follow a discernible pattern most of the time. Traversal would also be better-suited for grocery stores because of the narrow (and potentially congested) aisles, which could make it difficult for the worker to turn around.

Valle et al. [19] investigated the Joint Order Batching and Picker Routing Problem (JOBPRP). Their main task is to find the minimum-cost closed walk where each picker visits their required locations. They described three integer programming formulations for the JOBPRP and introduced valid inequalities (cuts) for the problem. The main contribution of this paper is that the computational performance is significantly improved with valid inequalities.

III. Methodology

A. Notations

In the methodology, the following variables are used

- l Length of an aisle
- w Center-to-center distance between aisles
- b Distance from staging area to the beginning of storage area
- V Travel speed
- D_k Travel distance for batch k
- AT_j Arrival time of order j
- RT_j Ready time of order j
- OT_j Pick time of order j
- BT_k Pick time of batch k
- ST_k Start time of batch k
- A_k Set of all aisles to be visited for batch k
- N_k Number of aisles visited to pick batch k
- t_c Extraction time of an item
- c_j Number of line items for order j
- B_k Set of orders in batch k
- B Batch size
- X_{jk} 1, if order j is in batch k; 0, otherwise

B. Routing Methodology

A model of the order picking in a grocery store was developed to be able to simulate the process. Fig. 1 shows the layout of a store and the travel path to pick items for a batch. Once a batch of orders is ready, the worker starts from the staging area and travels to the appropriate aisle(s) to retrieve the products (indicated by storage locations with an "X"), then travels back to the staging area.

The worker only visits aisles which contain items that are to be picked and uses the traversal policy, entering from one side of the aisle and exiting from the other side of the aisle. Also, if there is an odd number of aisles to be visited, the worker travels one extra aisle, to get back to the end where they started. This means that the value of N_k is either equal to $|A_k|$ (if the number of aisles in the set A_k is even) or to $|A_k|+1$ (if the number of aisles in the set A_k is odd).

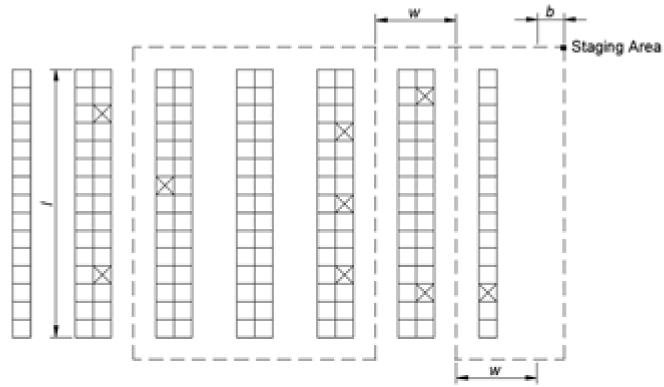

Fig. 1. Layout and travel path of the store

The total distance traveled by a worker to fulfill a batch of orders includes travel from the staging area (and back); travel through the N_k aisles where items to be picked are located; and travel to the last aisle where items are to be picked, as shown in (1).

$$D_k = 2b + (N_k \cdot l) + 2(\max\{A_k\} \cdot w) \tag{1}$$

The total time spent by the worker to pick line items includes the time to travel the distance as calculated in (1) and the time to extract items from the shelf. The time to pick a batch is shown in (2) and the time to pick an order is shown in (3).

$$BT_k = \frac{D_k}{V} + t_c \cdot \sum_{j \in B_k} c_j \tag{2}$$

$$OT_j = \sum_{k=1}^{B} \frac{BT_k}{|B_k|} \cdot X_{jk} \tag{3}$$

Ready time is the total time required for a customer order before it is ready for customer pickup. Ready time begins when the order arrives to the store and ends when all the items in the order are picked and brought to the staging area. The ready time of order j can be calculated using (4).

$$RT_j = [\Sigma(ST_k + BT_k)\cdot X_{jk}] - AT_j \tag{4}$$

IV. Results

The objective of the testing is to evaluate the performance of two strategies for batching orders as they arrive to evaluate how each strategy affects workload and customer service.

A simulation of the order fulfillment process was done to evaluate the batching strategies under different conditions. For each set of conditions, the simulation was run for 50 days with an average of 26 orders per day.

To conduct the analysis, a grocery store dataset with necessary information like type of products ordered and the item(s) in an order was necessary. The publicly available Food-mart dataset [20], was used for the analysis.

The parameters assumed for the store are given in Table I:

TABLE I. STORE PARAMETERS

Parameter	Value
Number of aisles	16
Distance to staging	20 ft
Center-to-center distance in aisle	10 ft
Length of aisles	100 ft
Travel speed	1 ft/sec
Extraction time	10 sec/line

The following assumptions were made for the simulation:

- A worker is always available to pick a batch when it is ready
- Items are assigned to aisles by product category, so demand is randomly distributed among aisles
- C&C service operates for 9 hours a day

For each customer order, the inter-arrival time was generated randomly based on the exponential distribution. Immediately upon arrival, an order enters a queue and waits until its batch is complete, which is either when the necessary number of orders have arrived or the necessary time has elapsed. Then, the orders are dispatched to be picked.

For each batch, pick time is calculated by considering which aisles need to be visited to retrieve all of the items in all of the orders. As shown in (3), order pick time is calculated by dividing batch pick time by the number of orders in a batch, so all orders will have the same mean pick time.

Ready time is calculated separately for each order by taking the amount of time an order waited in the queue for picking to start and the amount of time taken for picking the batch it was in.

For a batch, its ready time is calculated as the largest ready time for an order in the batch (i.e., the earliest-arriving order in the batch).

A. *Order-Based Batching*

As batch size increases, picking becomes more efficient, since more items are picked with only slightly more travel. However, larger batches also reduce customer service, since most orders will wait longer after they are received for the batch to be ready to begin picking.

To examine how batch size affects the pick time and ready time of orders, pick time and ready time were calculated for different batch sizes using a mean inter-arrival time of 20 minutes. The results of OBB per batch are shown in Fig. 2.

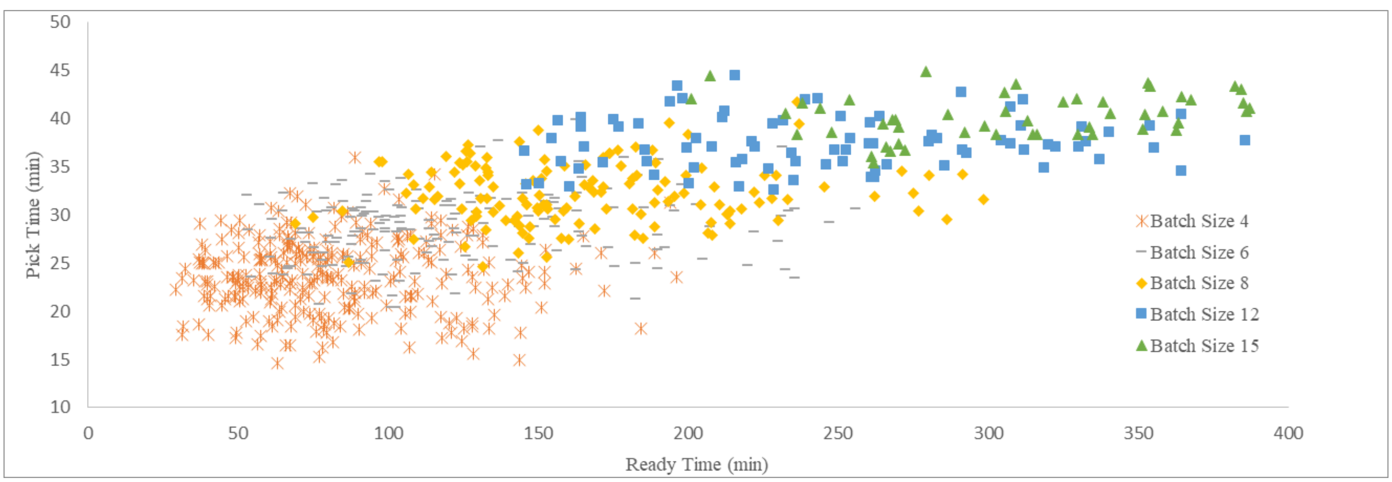

Fig. 2. Pick time per batch vs ready time per batch for OBB

Fig. 2 shows that as the size of the batch increases, ready time per batch and pick time per batch also increase. Ready time increases because the time orders wait in the queue also increases. Pick time increases because the probability of visiting more aisles in the store increases, which raises the travel time.

However, the pick time begins to level off for larger batch sizes. Larger batches contain more lines, which increases extraction time slightly, but the majority of pick time is travel, which has an upper limit. This system contains 16 aisles, so with a batch size of 12, workers are visiting all aisles for most batches. Therefore, further increases to batch size only add time for extraction.

From Fig. 2, it can also be seen that the variability in pick time is much greater when the batches are small. This is because of the large variation in the number of aisles that are visited and in the last aisle that must be visited. Again, because batches that are large (relative to the number of aisles) will typically require visiting all aisles, the variation for these batches is mainly due differences in the number of lines in a batch.

Because picking time increases only slightly when batch size is large, picking is more efficient with larger batches. More orders are filled without much additional time for the worker. Therefore, it makes more sense to also look at results of pick time and ready time per order instead of per batch.

The OBB results calculated on a per order basis are shown in Fig. 3. To prevent the graph from becoming too cluttered, there is only one datapoint for each batch, based on the mean pick time and mean ready time for the orders in the batch.

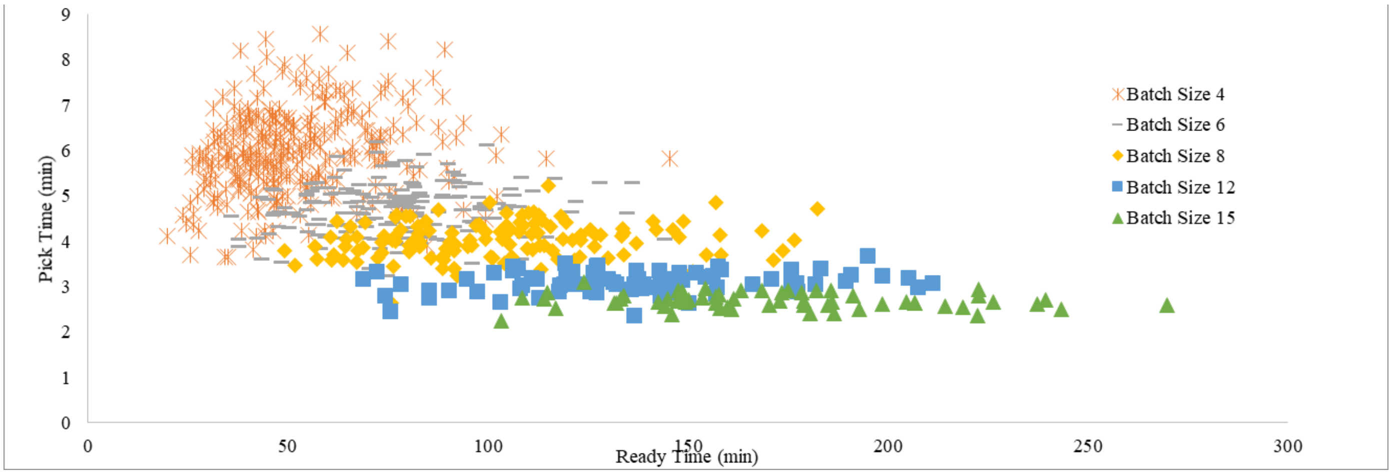

Fig. 3. Pick time per order vs ready time per order for OBB

The per-order results in Fig. 3 show the opposite trend of the per-batch results. The highest pick time per order occurs for the smallest batches, since the travel for these batches is only slightly less than for large batches, but is distributed among a much smaller number of orders. Small batches still show a much wider range of values for pick time compared to large batches.

Large batches again show a higher ready time than small batches, but the values are reduced from the per-batch results. Large batches have a higher ready time because orders wait in the queue longer before picking begins. However, since ready time is calculated on a per-order basis in Fig. 3, many orders have a small time in the queue and therefore have a small ready time. This is not reflected when per-batch ready time is considered because the ready time for a batch is represented by the maximum ready time for an order in that batch.

Table II gives the mean values of ready time and pick time across all batches for each batch size. These results show that with the increase in the size of the batch, the mean ready time per order increases and the mean pick time per order decreases.

TABLE II. PERFORMANCE OF THE OBB STRATEGY FOR DIFFERENT BATCH SIZES

Batch Size (orders)	**Mean Ready Time per Order (minutes)**	**Mean Pick Time per Order (minutes)**
4	52.3	5.9
6	76.5	4.7
8	98.6	4.0
12	138.6	3.1
15	176.5	3.0

B. Time-Based Batching

To evaluate time-based batching, the same interarrival times and the same list of orders were used as for OBB. Based on the mean interarrival time of 20 minutes, the batch interval of 30 minutes has an expected batch size of 1.5 orders. The remaining batch intervals tested (60, 90, and 120 minutes) correspond to expected batch sizes of 3, 4.5, and 6 orders, respectively.

Pick time and ready time were calculated for different batch intervals and the results of TBB per batch are shown in Fig. 4.

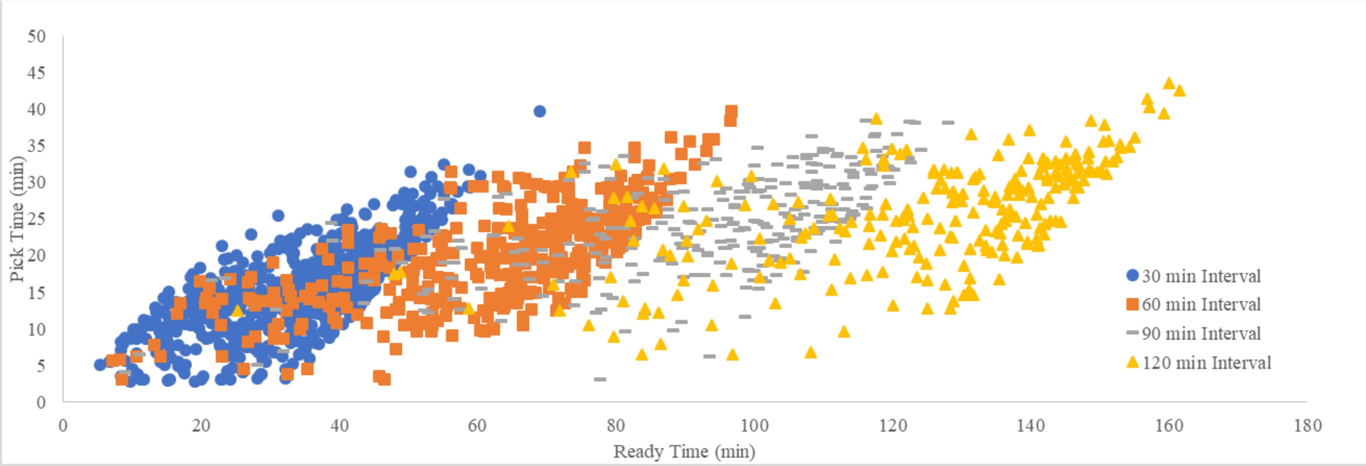

Fig. 4. Pick time per batch vs ready time per batch for TBB

Fig. 4 shows that as the batch interval increases, the minimum and maximum pick time per batch increase slightly. There is a lot of variability in pick time across all time intervals because TBB allows a wide variation in the number of orders in a batch.

The ready time per batch increases significantly as the batch interval increases. This is due to the larger queue time that is forced by the batch interval.

For each of the different data sets, there is an apparent upper limit along which the values on the right side of the data set appear to be aligned. This boundary corresponds to the value of the batch interval: since ready time includes the waiting time for the batch to be formed, orders that arrive near the start of the batch interval must wait for the entire interval for picking to begin, but they never have to wait more than the batch interval. The (x,y) coordinates of a data point on this boundary will be (*Batch Interval* + *Pick Time*, *Pick Time*).

The results of analyzing the TBB values in Fig. 4 on a per order basis are shown in Fig. 5.

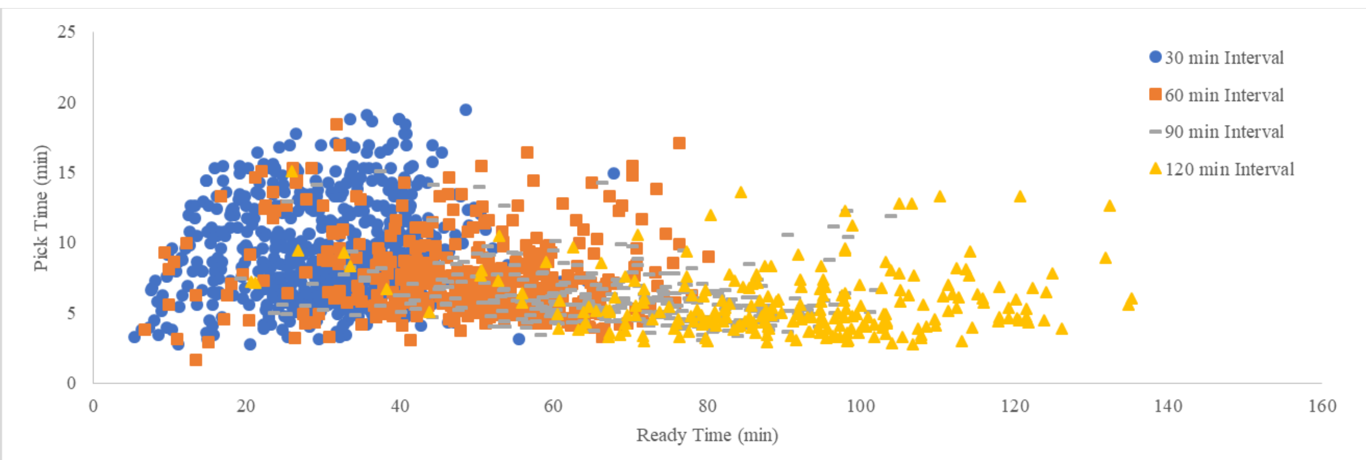

Fig. 5. Pick time per order vs ready time per order for TBB

Fig. 5 shows that the times in TBB follow a similar trend to those in OBB. The pick time per order decreases and the ready time per order increases with an increase in the batch interval.

However, the TBB results show more variability in pick time compared to the OBB results. This is because a batch under TBB could have 1 order or it could have double the expected number of orders, depending on the interarrival times of the individual orders. Even for very large batch intervals, a batch could consist of one or two orders that arrive near the end of the interval, leading to a low ready time, since this is based on when the orders arrive and not the start of the interval.

The mean ready time and mean pick time for the different intervals are shown in Table III.

TABLE III. PERFORMANCE OF THE TBB STRATEGY FOR DIFFERENT BATCH INTERVALS

Batch Interval (minutes)	Mean Ready Time per Order (minutes)	Mean Pick Time per Order (minutes)
30	44.2	8.0
60	51.9	6.4
90	70.8	5.4
120	90.5	4.8

The trends in these results are similar to what was observed for OBB, with ready time increasing and pick time decreasing as the size of the batch increased.

C. Effect of Order Interarrival Times

Mean pick times per order and ready times per order were calculated for different values of mean time between order arrivals and different batch sizes. the results are shown in Fig. 6 for OBB and Fig. 7 for TBB.

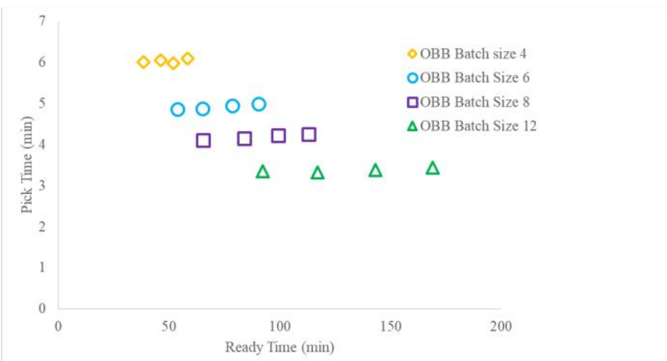

Fig. 6. Results as interarrival times for orders change under OBB

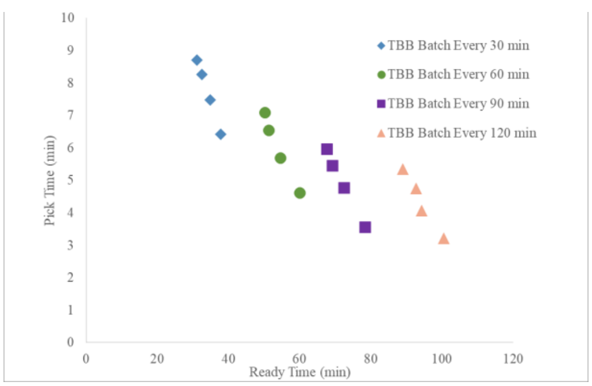

Fig. 7. Results as interarrival times for orders change under TBB

In Fig. 6, the change in mean ready time is due to increases in interarrival time. With a larger time between orders, orders must wait in the queue longer for the necessary number of orders to arrive. However, mean pick time per order did not change for OBB much even though there is a big change in the mean time between the orders. This is because in OBB, a batch is released for picking when a fixed number of orders have arrived, which means the number of line items to be picked for a batch is not affected by the interarrival time.

In Fig. 7, the increases in ready time under TBB correspond to *decreases* in the mean time between the orders. As orders arrive more quickly, batches will be larger, requiring more time for picking. This effect is also shown in TBB with a significant decrease in pick time per order as interarrival time decreases. Although the larger batches require more time to be picked, the pick time per order is lower.

In order to have a fair comparison between OBB and TBB, the batch size for OBB and the batch interval for TBB were set so that the expected number of orders per batch were the same based on the mean time between orders.

The results are shown in Table IV for OBB and Table V for TBB. Table VI shows the percent different between the two strategies. The percent differences in Table VI represent the change if the OBB strategy were switched to the TBB strategy.

TABLE IV. OBB RESULTS

Batch Size (orders)	Order-Based Batching		
	Mean Time between orders (min)	***Mean Ready Time (min)***	***Mean Pick Time (min)***
6	10	53.0	4.8
4	15	46.3	6.0
3	20	39.9	7.0

TABLE V. TBB RESULTS

Batch Interval (min)	Time-Based Batching		
	Mean Time between orders (min)	***Mean Ready Time (min)***	***Mean Pick Time (min)***
60	10	58.8	4.6
60	15	54.8	5.7
60	20	52.1	6.4

TABLE VI. COMPARISON OF OBB AND TBB RESULTS

Expected Batch Size (orders)	Mean Time Between Orders (min)	Difference in Mean Ready Time	Difference in Mean Pick Time
6	10	10%	-4%
4	15	16%	-5%
3	20	23%	-9%

Based on the results, OBB offers a shorter ready time than TBB. This is because the queue time for the last order in a batch under OBB is always zero, but in TBB this is not true. Since queue time is a part of the ready time, OBB produces a lower ready time.

The pick time for OBB is slightly higher than TBB because TBB is likely to have some batches in which the number of orders in the batch are slightly higher than the OBB batch size, due to variation in the interarrival times. For some days, this will lead to batches with zero orders—that is, no orders arrived in the batch interval—and this is particularly likely when the expected batch size is small. On days when TBB is able to complete the same orders as under the OBB strategy, but with fewer batches, the mean pick time per order on those days is smaller than OBB, which leads to a reduction in the overall mean pick time.

V. CONCLUSIONS

Simulation testing of the OBB and TBB batching heuristics shows that the OBB heuristic produces a lower mean ready time, with a slight increase in mean picking time. Deciding which heuristic is better for implementation in a given store depends on the store's priorities—whether they are competing based on the speed with which orders are filled or the cost of the service.

In general, the OBB strategy (and the lower ready time it produces) may be more desirable for stores. Although it will cause a slight increase in cost, customers who use this service are likely to be sensitive to the speed of the service rather than its cost. In addition, the pick time saved if a store choses TBB may not be used productively if the workers end up being idle waiting to begin their next batch.

Future work will examine picking schedules for the two strategies and determine how staffing requirements change as expected batch size and interarrival time change. This will eliminate the assumption in this testing that a picker is always available when a batch is ready.

In addition, further work is planned on developing a mathematical model of the picking process. The model for picking time in this paper was intended only for use in calculating the pick time and ready time in the simulation testing. Future work will develop a more rigorous model that can be used to determine optimal values of batch size or batch interval under a store's operating conditions.

REFERENCES

[1] Y. Benn, T. L. Webb, B. P. I. Chang, and J. Reidy, "What information do consumers consider, and how do they look for it, when shopping for groceries online?," *Appetite*, vol. 89, pp. 265–273, Jun. 2015.

[2] V. Ilyuk, "Like throwing a piece of me away: How online and in-store grocery purchase channels affect consumers' food waste," *J. Retail. Consum. Serv.*, vol. 41, pp. 20–30, Mar. 2018.

[3] J. Elms, R. de Kervenoael, and A. Hallsworth, "Internet or store? An ethnographic study of consumers' internet and store-based grocery shopping practices," *J. Retail. Consum. Serv.*, vol. 32, pp. 234–243, Sep. 2016.

[4] S. Saskia, N. Mareï, and C. Blanquart, "Innovations in e-grocery and Logistics Solutions for Cities," *Transp. Res. Procedia*, vol. 12, pp. 825–835, 2016.

[5] D. Vyt, M. Jara, and G. Cliquet, "Grocery pickup creation of value: Customers' benefits vs. spatial dimension," *J. Retail. Consum. Serv.*, vol. 39, pp. 145–153, Nov. 2017.

[6] E. Suel and J. W. Polak, "Development of joint models for channel, store, and travel mode choice: Grocery shopping in London," *Transp. Res. Part Policy Pract.*, vol. 99, pp. 147–162, May 2017.

[7] J. Chu, M. Arce-Urriza, J.-J. Cebollada-Calvo, and P. K. Chintagunta, "An Empirical Analysis of Shopping Behavior Across Online and Offline Channels for Grocery Products: The Moderating Effects of Household and Product Characteristics," *J. Interact. Mark.*, vol. 24, no. 4, pp. 251–268, Nov. 2010.

[8] E. Huyghe, J. Verstraeten, M. Geuens, and A. Van Kerckhove, "Clicks as a Healthy Alternative to Bricks: How Online Grocery Shopping Reduces Vice Purchases," *J. Mark. Res.*, vol. 54, no. 1, pp. 61–74, Feb. 2017.

[9] R. De Kervenoael, A. Hallsworth, and J. Elms, "Household pre-purchase practices and online grocery shopping: E-grocery pre-purchase trajectories," *J. Consum. Behav.*, vol. 13, no. 5, pp. 364–372, Sep. 2014.

[10] V. J. Khan and R. Brouwer, "The relation between customer types in a real supermarket compared to a virtual supermarket," *J. Virtual Worlds Res.*, vol. 9, no. 1, 2016.

[11] N. S. Muhammad, H. Sujak, and S. A. Rahman, "Buying Groceries Online: The Influences of Electronic Service Quality (eServQual) and Situational Factors," *Procedia Econ. Finance*, vol. 37, pp. 379–385, 2016.

[12] O. Martinez, B. Tagliaferro, N. Rodriguez, J. Athens, C. Abrams, and B. Elbel, "EBT Payment for Online Grocery Orders: a Mixed-Methods Study to Understand Its Uptake among SNAP Recipients and the Barriers to and Motivators for Its Use," *J. Nutr. Educ. Behav.*, Nov. 2017.

[13] A. Fagerstrøm, N. Eriksson, and V. Sigurðsson, "What's the 'Thing' in Internet of Things in Grocery Shopping? A Customer Approach," *Procedia Comput. Sci.*, vol. 121, pp. 384–388, 2017.

[14] M. Jothibasu and S. Boopathy, "A Fast Cloud Based Pervasive Method of Cart Billing System for Supermarket Using Real Time Technology," *Int. J.*, vol. 8, no. 3, 2017.

[15] J. S. Winter, "Surveillance in ubiquitous network societies: normative conflicts related to the consumer in-store supermarket experience in the context of the Internet of Things," *Ethics Inf. Technol.*, vol. 16, no. 1, pp. 27–41, Mar. 2014.

[16] E. P. Chew and L. C. Tang, "Travel time analysis for general item location assignment in a rectangular warehouse," *Eur. J. Oper. Res.*, vol. 112, no. 3, pp. 582–597, 1999.

[17] X. Xu, T. Liu, K. Li, and W. Dong, "Evaluating order throughput time with variable time window batching," *Int. J. Prod. Res.*, vol. 52, no. 8, pp. 2232–2242, Apr. 2014.

[18] C. G. Petersen, "An evaluation of order picking routeing policies," *Int. J. Oper. Prod. Manag.*, vol. 17, no. 11, pp. 1098–1111, 1997.

[19] C. A. Valle, J. E. Beasley, and A. S. da Cunha, "Optimally solving the joint order batching and picker routing problem," *Eur. J. Oper. Res.*, vol. 262, no. 3, pp. 817–834, Nov. 2017.

[20] MySQL Foodmart Database (2008). Available from http://pentaho.dlpage. phi- integration.com/mondrian/mysql- foodmart-database . Last accessed 10.5.18.