Optimization for Order Batching Problem using Scheduling and Route Strategies

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RESUMEN

Dentro del manejo de almacenes, la recolección de órdenes es uno de los procesos más importantes dentro de una compañía, este proceso representa el 55% de los costos del almacén. Por varias décadas se han realizado diversas investigaciones para lograr una posible solución a este problema en particular. La mayoría de estos estudios se enfocan en el Problema de procesamiento de órdenes por lotes (OBP), el cual es el proceso de consolidar órdenes en lotes en base a sus fechas de entrega, para reducir tiempos y costos mediante la generación de una ruta de secuencias para recolectar los artículos. Este trabajo presenta una formulación diferente del problema, en dónde se compara el efecto de primero procesar los lotes y posteriormente generar una ruta de recolección, contra el proceso de generar los lotes y la ruta mediante una estrategia de ruteo en un almacén real.

PALABRAS CLAVE

Almacén, Problema de procesamiento de órdenes por lotes, Optimización.

ABSTRACT

In warehouse management system, order picking is one of the most important processes in a company; It involves nearly 55% of the warehouse costs. For many decades there have been large investigations and developments of possible solutions for this particular problem. Most of the studies have been focused in the Order Batching Problem (OBP), which is the process of consolidate orders into batches according to its due dates. In order to reduce time and costs, this process generates a sequence and a possible route to pick the items. This work presents a different problem formulation pursuing a progress at OBP solution by comparing the effect of first batching orders using a heuristic and then generate a route, against using route strategies to batch orders, in a real warehouse system.

KEYWORDS

Warehouse, Order Batching Problem, Optimization.

INTRODUCTION

Warehousing is an important and costly element in the supply chain because it must provide a service on time and satisfy costumer necessities. Its costs represent on the verge of 14% to 36% of the final product costs. [1] This cost includes storage, staff, equipment, space associated to it, among others. Although each warehouse is unique, activities within it are similar in all of them. [2] Therefore, in warehouses with mainly manual systems or those with very intensive operation with automated systems; an efficient process is crucial in terms of cost and service provided. Warehouses can be classified according to their main roles in the Supply Chain Management (SCM) in: consolidation centers, cross-dock centers & trans-shipment points.

According to Piaw, [3] warehouse processes can be divided in five main phases. The first phase is called receiving process: Large orders arrive by truck or internal transport (in case of a production warehouse). At this stage, the products may be checked or transformed (e.g., repacked into different storage modules) and wait for transportation to the next process. Sometimes, an assignment policy is used to determine the truck allocation to docks.

The second phase is called storage process: Incoming articles are placed in storage locations; there are several policies such as, the random storage policy where the location decision is taken by the operator, other is the dedicated storage policy where a particular location is prescribed for each product to be stored. There are also some special areas within the warehouse (e.g. reserved area, where products are stored in the most economical way; or the forward area; where products are stored for easy retrieval by an order picker). If any of these or other areas exists, a storage policy is needed for each space.

The third phase is called order picking process: Retrieval of items from their storage locations. The order picking process arises because of the nature of incoming articles volume (i.e. incoming articles are typically received and stored in large volume meanwhile customers' orders are the combination of several items, articles or products in small quantities).

The fourth phase is called checking and shipping process: In the checking process, orders are checked to ensure quality, quantity, labeling customer´s information, accuracy and right condition of the items to be picked; all these characteristics must coincide to orders and due dates. If there is an incomplete or inaccurate order a re-order pricking process should be done until costumer's requirements are fulfilled. Following this stage, the shipping process is performed enclosing mainly packing and loading, the complete quantity of items must be carried out to any transportation vehicle (e.g. trucks, trains, etc.) in order to be shipped, and consecutively reported to the inventory control.

The fifth and last phase that is not always integrated in warehousing but is important to name it because is a crucial point to build an efficient system is the delivery process: This process basically consists in delivering the consignment to the consignee at the agreed time and place. The process must consider the delivery areas, number of destinations convened, different location and number of orders to satisfy the requirement. With this event the order is considered fulfilled, representing the final phase in the warehouse process. [4]

It has been stated that the logistic cost of the order picking process is about the 55% of the total warehouse costs, and the time that is invested is up to 50% of the total time of all process [5]. In this sense, it is not hard to see that an efficient picking process can reduce cost and time in the warehouse operations and in the supply chain. This makes the picking process a central issue to develop improvements that would generate direct benefits in the enterprise.

The order picking process is well known in the literature as the order batching problem (OBP). It aims to minimize the total processing time while assigning customer orders to batches which can be transformed to determine the optimal composition of batches. OBP is classified as a NP-hard problem [4]. Therefore, the decision variables have to be wisely analyzed in order to optimize resources while delivering the products at the right time.

The OBP is subjected to diverse constraints such as: orders to be processed, the due dates for each item, the picking method used, the warehouse layout, number of racks, just to mention some of them. Customer orders consist of number of order lines. Each order line represents one product or article that has to be shipped to the customer in a certain quantity called the order line quantity. Those order lines which should be processed together are contained on a picking list. The picking list can be gathered either by the order lines of a single customer order (single order picking or picking-by-order) or may be consolidated, i.e. it can encapsulate or group articles destined for the same customer into picking orders (pick-by-order or batch picking).

It is very important in distribution and material warehouses to consider the order's due date when conforming the order batching. Mainly because the batches schedule transportation to an internal or external location has to be done with certain due dates to avoid delivery and/or production delays, shortage or excess inventory and customer's dissatisfaction among other situations. If due dates are not considered, orders can be batched inaccurately creating a miscalculate delivery, the merchandise might arrive before or after the time required. Henn [6] defined the tardiness of a customer order as "the positive value between the completion times of a customer order with its due date" meanwhile, the completion time is that time than a picker takes to finish his tour of gathering all items and comes back to the starting point.

The OBP can be performed either manually, or automated. Automated systems are more productive and accurate, facilitate order picking and provide added value activities (e.g., picking time is reduced, better customization and regulation of items is improved by labelling them). It represents a viable option for assembly operations, where companies adopt postponement strategies. The disadvantage of these systems is the cost; it is more expensive to have an order picking automated than manually in most scenarios and this is not convenient for the enterprise [6].

Within the automated systems, the parts-to-picker systems involve a significant automation of carousels and mini-loads that are linked to a computer control center. The carousels have the responsibility to pick and present the items to pickers in an appropriate sequence; therefore, order pickers do not move within the system. There are different parts-to-picker systems but the most common are the Automated Storage1 and Retrieval Systems (AS/RS), also known as mini-loads. These systems use cranes that go from aisles to bounds retrieving one or more unit load (item). Other systems used are the Vertical Lift modules (VLM). They also bring unit loads to the order picker in an automated manner, but in this case, the order picker is responsible for the quantity of each item taken.[7]

Manual systems are usually applied in small warehouses where there is not enough space to install machines, and for small items that can be easily handled by an operator. These systems are also cheaper to implement and maintain, but with labor-intensive. Even tough, they are the most common ones used in industry.

In manual systems, pickers (person that realize the labor) play an essential part in the system. Basically a picker takes a picking list and travels within the warehouse to complete the list required. [4] There are two types of picker-to-part systems: low- level where items are picked up from storage racks while they travel along the aisles; and the high-level, where the pickers travel to the picking locations on board of a vehicle (normally a fork lift). Once the location has been reached, the truck stops in front of the assigned location and waits for the collecting order.

This paper is focused on solving the OBP in a real warehouse system where a preliminary problem is analyzed.

ORDER BATCHING PROBLEM

The manual OBP involves one or multiple agents moving items within a warehouse from their corresponding storage locations to the receiving or shipping area. The order picking normally involves two main phases: batch formation (scheduling customer orders), and route strategies to picking items from their storage locations.

Batch formation

In a single order picking policy, each order is taken in one picking tour, this situation could be convenient when a small amount of orders are picked. Nevertheless, product movement within warehouses is simplified by consolidating orders into batches. Therefore, an efficient organization of the order batching process is needed when dealing with big amounts of orders from different costumers. The problem of batch formation can be defined as finding the orders of constructed batches to be processed further. This activity should be done before the retrieval process, i.e. picking customer orders is performed. [8]

Batching is a popular strategy to improve productivity due to the reduction in order picking travel time. Instead of traveling through the warehouse to pick a single order, the picker completes several orders with a single trip. Hence, the travel time per pick up can be reduced. There are some trade-offs in the order picking process: if batch sizes increase, the flow rates to pick stations will decrease, leading to lower utilization of the stations. On the other hand, a larger number of orders in a batch mean longer service time at pick stations. It also implies a larger batch size and longer queuing time for batch completion and longer processing time in the following process. Therefore an interesting topic is to determine when to batch orders, how to batch orders, and to determine the impact of batch size on the system performance.

There are basically two criteria for batching: the proximity of pick locations and time windows. Proximity batching assigns each order to a batch based on proximity of is storage location. The major issue in proximity batching is how to measure the proximities among orders; the objective is to minimize the lead-time of any batch [9]. In the case window batching time; the orders arriving during the same time interval, called a time window, are grouped as a batch, these orders are then processed simultaneously, in the following stages: If the order spitting is not allowed, it is possible to sort items by order during the picking process. Picking strategy is often referred as the sort-while –pick picking strategy, the optimal picking batch size is determined in a straightforward manner. [4]

Warehouses operate usually in a first-in first-out (FIFO) basis with respect to the unit loads of a particular item to avoid spoilage and obsolescence of the product held in the unit load in this way. It might be possible reduce the makespan when forming a batch while minimizing delays on customer responses. Once the batch formation has been performed, a routing policy may be needed and an order sequencing.

Route strategies

The route strategies are defined as the processes of identifying the minimum distance which would be traveled by the picker in a warehouse upon identifying which order should be picked first [9]. Therefore, the main objective of the routing strategies is to find an optimal sequence for the items that are on the pick list. This route allows traveling a minimum distance route through the warehouse.

The routing problem in a warehouse is a scenario in the Traveling Salesman Problem (TSP). In practice the problem of routing pickers is mainly solved by using heuristics, like the S-Shape, the return method, midpoint method and the largest gap strategy. [10], [17]

- The S-Shape heuristic, is a route strategy where all the aisles are visited in an S shape, it is also called the transversal strategy, because the picker enters an aisle from one end and left the aisle from the other end.
- Return Method uses a procedure where the dock returns in each pick aisle that contains the items to be picked, therefore it crosses and don´t travel along one single aisle. For the Midpoint method the warehouse is divided in an “artificial” midpoint line, with an upper and a lower section. The picker collects all the items in the upper section, and then it collects the lower section.
- The largest gap strategy determines two sections in a warehouse; it is based on the largest distance between two items that are going to be picked.
- The midpoint method, this strategy divides the warehouse in two sections, the compilation from the first stage access in the front part of the cross aisle, meanwhile the items located in the other access from the back cross aisle, the picker traverses to the back half by either the last or the first aisle.

STATE OF THE ART

The OBP has been analyzed by different authors under two main frameworks: the automatic and the manual system our interest aims the late. An overview of the developments in academic literature can be found in references [6], [11], [13] and [16] to mention some of them. According to Henn, [6] the OBP resolution methods can be classify as: priority rule based algorithms, seed algorithms and saving algorithms. Also in the literature can be find a mix of different techniques and algorithms what we call hybrid algorithms.

Priority rule based algorithms

These algorithms consist on assigning priorities to a certain list of activities, processes or resources. In the OBP, a priority is assigned to every order to be used in a second stage to batch sequentially in decreasing order of priority. A constraint that cannot be violated, is the capacity of the picker device. The most usual rules are Next-fit, First –fit, Best-fit and the First come first served (FCFS) rule. [12]

In the next fit rule, it is kept a single active batch at each time, if the next item cannot be packed into the active batch then, the item must wait until a new batch is active to be placed within it. The First fit rule is used when it exist more than one batch available to where an order fits, so the item is always placed into the batch with the lowest index where it fits. The best fit rule is similar to the first fit rule, but it takes in count the batch where the order fist best, considering not only the batch with the lowest index, but also the batch with the width, height and area that fists best. [14] According to Horvat [13], the most straightforward rule is the FCFS because it assigns priorities based on which customer order arrived first and it is not only focused on the depots available.

Andrinsyah, *et al.* [18] uses the FCFS rule in an automated order picking system taking in count two priority rule variants the FCFS and a non-FCFS sequence, proposing a model that aggregates stochasticities that contribute to the flow time performance. The authors conclude that the effect of both policies in combination with the aggregate model gives a flow time in both cases with a good accuracy in prediction of the flow time distribution of products and orders, so this technique is a good alternative for stochastic systems.

Also, Henn *et al.* [19] compares the effect of the FCFS and different batching policies in complement with metaheuristics such as Iterated Local Search (ILS) and the Ant Colony Optimization. It is compared the improvement among these methodologies, taking as an initial point the FCFS algorithm and considering that all customer orders have the same priority, generating a random sequence in customer orders, according to which orders are assigned to each batch. At the end the result presents that the best improvement reduces the length of the picking tours in more than a 20% compared with the FCFS.

Seed algorithms

The aim of seeds algorithms, also known as construction algorithms, is to make iterative searches using different seeds until there is not a better solution. The basic idea behind this technique is to use a seed order (initial order) to be first selected based on seed selection rules for a batch and afterward unassigned orders are added into the batch according to order addition rules until the order picker is filled to capacity. In the OBP, this algorithm constructs batches sequentially and in two phases. The first phase consist on choosing an order that is going to be the seed, according to the seeds selection rule, in the second phase, the additional orders must be added to the batch according to the rule named accompanying-order selection rule, until there are no orders left to be added without violating the capacity restriction. [13]

Elsayed *et al.* [16] present the use of this algorithm in OBP. The algorithm generates batches in two phases, in the first one a seed order is chosen according to the seed selection rule (distance to the original point), and in the second phase, the additional orders are added to the batch until there are not orders left to add and according to the constrains, so that the batches are constructed until all customer orders have been assigned to a batch, in the study the algorithm develops an improvement in the OBP. There is another study presented by Pan and Lio [18] where there are compared 17 different algorithms, using four seed selection rules and four order addition rules for the order batching problem, making a combination of seed selections with other heuristics. As result they obtain that the minimum travel time is obtained with the seeds rules

Saving algorithms

These kinds of algorithms are based on the notion of saving from the work of Clarke and Wright (C&W) [19] which was first applied to the vehicle routing problem (VRP). Saving algorithms were born from the idea of time/distance saving that can be obtained by combining two orders in one picking tour as compared to the situation where both orders are picked individually. These algorithms look for the time/distance reduction travelled when orders are picked in the same tour. Orders are added to batches according to the largest saving without violating the capacity of the picker device. Savings are recalculated every time an order is added to a batch or two batches are joined together [12]. There are two main versions of the C&W algorithm: the parallel and the sequential version. In the parallel version, it is built more than one route at a time, considering that the capacity of the picker device is not exceeded; on the other hand, the sequential version builds only one route to pick items without overpassing the capacity of the picker device, using booth is very useful in OBP, depending on the case. [14]

Hybrid algorithms

The state of the art of different authors that had proposed a solution for the OBP, is presented using the previous algorithms and other simulation or optimization tools for the solution in different picking systems.

In the work of Elsayed *et al.* [15] is developed an efficient procedure for sequencing, batching and processing in AS/RS system, where the objective was minimize the sum of the earliness and tardiness penalties in the batches and sequence orders, they used a bisectional search method to sequence the orders, seed algorithms to make the batches and for determining the time for the S/R machine. They used the Weighted Absolute deviation problem, when they got the results of each one, a formula was applied, they call it the traffic congestion ratio (TCR), this must be close to 1.

De Koster *et al.* [16] searched to minimize the total travel time with a robust algorithm, simple enough to use in practice. It is used FCFS, and three different types of C&W, the Equal algorithm to select a combination of two orders as a seed. Small-large (SL) algorithm makes a distinction between large orders and small orders for the batch formation, and as route strategies there where used S-shape and Largest Gap heuristic. A comparison between them was done and the best result was the C&W methodology in combination with the largest gap heuristic with an improvement of the 24% in the travel time.

The research of Roodbergen and De Koster [17] considered only the routing problem, where different routing methods in a warehouse were compared and analyzed with more than two cross aisles. They used a Branch and bound algorithm in combination with a new heuristic called the +Combined, incorporating a dynamic programming, this technique is compared with an Aisle-by-aisle heuristic, a Travel Salesman Problem (TSP) algorithm, S-shape and Largest gap heuristic. The best result was obtained with the +Combined, combined heuristic.

Henn *et al.* [6] searched and optimal solution for the Order Batching and Sequencing Problem (OBSP), where they focused on minimizing the tardiness for a set of customer orders. This research was based on an Earliest Due Date (EDD) rule, an Iterated Local Search (ILS) and the Attribute-Based Hill Climber (ABHC) for the batch formation with a subsequent comparison between them. The S-shape and Largest gap heuristics were used to create the routes. The ABHC, chooses the initial solution in the neighborhood structure and then a set of attributes, the customer orders are added by pairs, the best result was obtained with the ILS, presenting an improvement of 46% in the tardiness.

Azadnia *et al.* [11] aim to develop a model that reduces the orders procedure time and the travel time in the order picking procedure. This research applied Mining Association Rules with Weighted Items (MINWAL) to assign different priorities to customer orders according to the due dates. A calculation of the initial number of batches was performed by binary integer programming. Once a feasible solution is founded, a Genetic Algorithm (GA) with TSP is applied to solve the picker routing problem. The GA with Sequencing is used for the batch sequencing problem, the called this the ATGH model. As a result the ATGH make and improvement of 68.11% in the reduction time.

MODEL FORMULATION

A given enterprise offers the storage and distribution of food products with temperature control, it counts with a storage capacity of 7,000 tons, in 28 freezing chambers, in temperatures from -50°c TO -18°C, for our study case we are focusing only in one of this freezing chambers, aiming to solve the OBP for this particular case, where the due date of the product is one of the priorities of the process together with the optimization of the picking process.

In order to develop the research; it is taken in count the warehouse of the enterprise with their physical attributes. These characteristics are described in the following design. As showed in Figure 1, the warehouse is composed by 10 aisles each one with 10 divisions, and 3 floors within each division, hence, the warehouse can store 100 different items with a maximum capacity of 20 items per division. The total capacity of the warehouse is 2,000 items. The warehouse area is 18 m x 20 m depth. Each division has 1.20 m at front and 1 m depth, so each aisle is 12 meter of length and 1.0 depth. Between each aisle there is a 2 m hall. There are two aisles at the right and left end of the area that only have access from one side of the hall. The depot is located at the left side of the warehouse.

The model is formulated under the following assumptions:

- The warehouse and the distance between each article are considered symmetrical.

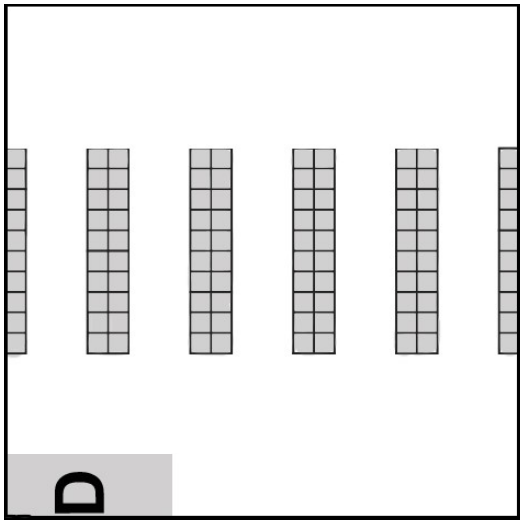

Fig. 1. Warehouse layout.

- There is only one vehicle with a maximum capacity of 50 items in all cases.
- The weight of the items is not taking into account.
- The velocity of the picker is not considered.
- The time of the picker to pick the items is contemplated as 0.

For the OBP, the model and heuristics were contemplated as follows:

Batch formation

Among the most common priority rules, the time window batching considered is the Earliest Due Date, which consists on making a list of the items according to the costumers' necessities, where the batch is produced. The objective is to make a batch list where two basic restrictions are taking into account. The first is the item due date or the expiration time, depending on the case. The second restriction is the capacity of the vehicle, when the capacity of the vehicle is at the limit and the items with the shortest date are in the batch this must be close and a new batch begins.

For this work it is taken in count a variant of the EDD rule that was applied to a warehouse with perishable articles called, the Earliest Due Date with Expiration Time (EDDET). Where the expiration date is considered instead of its due date, the constraints with the shortest expiration date and the vehicle capacity is estimated.

Route strategy

There are different methods to realize the route strategy, in the present project the S-shape heuristic is used, and in a second stage, the mathematical model form Toth[20] the CVRP.

The S-shape, heuristic was used to create the matrix of distance among each article creating a route with the form of an S, this matrix was integrated inside the model.

CVRP

The CVRP which aims to minimize the total travel distance was used to create the picker route.

This model uses the following nomenclature:

n: Number of customer orders

j: set of customer orders, where $j = \{1,2, \ldots ,n\}$

i: set of articles, where $i = \{1,2, \ldots ,n\}$

c: distance from article i to customer order j.

It was considered the Symmetric Capacitated Vehicle Routing Problem (CVRP) model used to solve the route is the one purposed by Toth and Vigomin[14] =which aims to minimize the total travel distance.

This is subject to the following constraints:

(2) And (3) are the constraints imposing that exactly one arc enters and leaves each vertex associated with a customer, respectively. Constraints (4) and (5) impose the degree requirements for the depot vertex. The constraint (6) impose the capacity- cut constraint imposing the connectivity of the solution and the vehicle capacity requirements. The equation (7) aims to eliminate sub tours in the route. The constraints (8) and (9) impose the capacity and the connectivity requirements, also eliminating insolated sub tours.

$$\min Z = \sum_{i \in V} \sum_{j \in V} c_{ij} x_{ij} \tag{1}$$

$$\sum_{j \in V(i)} X_{ij} = 1 \qquad \forall j \in V \backslash \{\mathbf{0}\} \tag{2}$$

$$\sum_{i \in V(i)} X_{ij} = 1 \qquad \forall i \in V \backslash \{\mathbf{0}\} \tag{3}$$

$$\sum_{i \in V} X_{i0} = K, \tag{4}$$

$$\sum_{j \in V} X_{j0} = K, \tag{5}$$

$$\sum_{i \in V} \sum_{j \in V} X_{ij} \geq r(S) \qquad \forall S \subseteq V \backslash \{0\}, S \neq \emptyset \tag{6}$$

$$\sum_{i \in V} \sum_{j \in V} X_{ij} \leq |S| - r(S) \qquad \forall S \subseteq V \backslash \{0\}, S \neq \emptyset \tag{7}$$

$$u_i - u_j + C_{x_{ij}} \leq C - d_j \tag{8}$$

$$d_i \leq u_i \leq C \qquad \forall_i \in V \backslash \{0\} \tag{9}$$

Instances

The software used for the solution of the problem was LINGO. For this particular problem we analyze the output history in the freezing chamber to create the instances from an ABC analysis, in order to obtain the 30 articles with more demand in the warehouse, this articles were selected to create the instances, the results of the ABC analysis can be seen in table I.

Table I. Results ABC.

No.	Kg	%	%ACUM	CLASS
1	4118	0.44127	0.44127	A
2	1691	0.18120	0.62248	A
3	1411	0.15120	0.77368	B
4	315	0.03375	0.80743	B
5	289	0.03096	0.8384	B
6	211	0.0226	0.86101	B
7	168	0.0180	0.87901	B
8	118	0.01264	0.89166	B
9	117	0.0125	0.90420	C
10	77	0.00825	0.91245	C
11	76	0.00814	0.92059	C
12	75	0.00803	0.92863	C
13	70	0.00750	0.93613	C
14	54	0.00578	0.94192	C
15	50	0.00535	0.94727	C
16	36	0.00385	0.95113	C
17	33	0.00353	0.95467	C
18	33	0.00353	0.95820	C
19	32	0.00342	0.96163	C
20	32	0.00342	0.96506	C
21	30	0.00321	0.96828	C
22	27	0.00289	0.97117	C
23	25	0.0026	0.9738	C
24	21	0.00225	0.97610	C
25	20	0.00214	0.97824	C
26	20	0.00214	0.98039	C
27	20	0.00214	0.98253	C
28	20	0.00214	0.98467	C
29	20	0.00214	0.98681	C
30	19	0.00203	0.98885	C

Three different instances where analyzed in the same warehouse were the capacity established is 100 different items, and each instance has 30 articles selected from the ABC, with a variable demand of 66, 60 and 62 items, respectively , in the first instance the 30 articles are taken from the the ABC analysis, the second instance, has only 14 items from the ABC and the rest are taken from the 100 different items that the warehouse store.

In the first part of the experiment EDDET was applied to the three instances with the variation of demand in the 30 articles. Two batches were obtained per instance due to the vehicle capacities, and then a route was made using the CVRP, for bout of them, as shown in the example of Table I.

The second experiment, only generated the route with the CVRP for the 3 instances, where the batch formation was obtained as part of the result of the model, as shown in the figures 2, 3 and 4.

In table II it can be seen the numerical results in each scenario, where distance and number of items per batch can be compared. Also the percentage of improvement at each instance per batch and per route is showed. The costs associated per item out of its due date and out of its expiration date are showed in comparison with the costs associated to the total distance per instance.

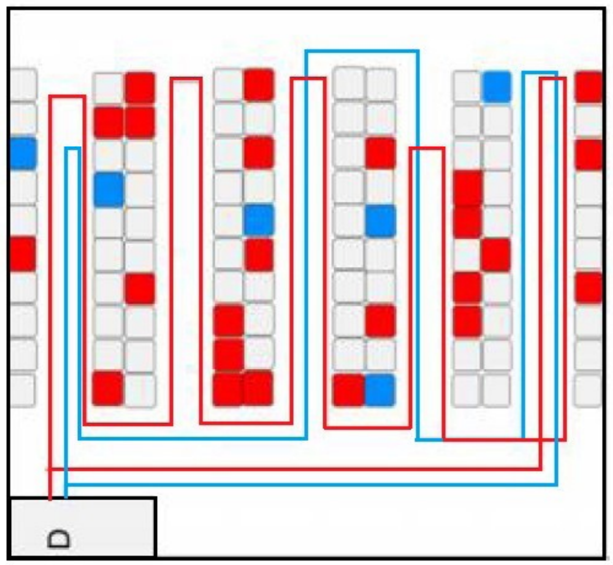

Fig. 2. Results for the first instance.

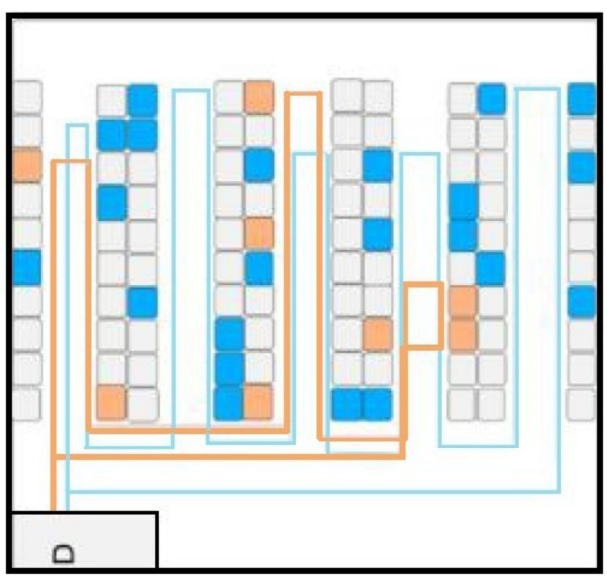

Fig. 3. Results for the second instance.

As it can be seen in the case of the EDD +VRP, the total distance traveled with two routes created was 303.5 m picking up all the items, in comparison with the EDDET+VRP with a distance obtained of 214.5 m. It is important to highlight that in both cases the number of items per batch is the same. In the case of the VRP the total distance traveled is 174.2 m and the items got per batch are 19 and 47, respectively. Therefore, the VRP presents an improvement of 43% in the total distance, and effectiveness in the batch formation of 94% is accomplished. Also, EDD and EDDET rules provide a performance improvement in batch formation; because the vehicle capacity is properly used in comparison with make the batches only with the VRP adding a capacity constraint to the model.

Table II. Example of the batch formation with EDDET.

Order of picking /Batch formation				For VRP	
Item	Demand	Dude date	Batch	Number	Item Demand
5	3	15	1	5	3
8	2	15	1	8	2
12	4	16	1	12	4
77	1	16	1	77	1
14	4	17	1	14	4
20	1	17	1	20	1
93	1	17	1	93	1
97	3	18	1	97	3
24	1	18	1	24	1
29	2	19	1	29	2
30	2	19	1	30	2
38	1	19	1	38	1
75	3	20	1	75	3
39	1	21	1	39	1
40	1	22	1	40	1
41	3	22	1	41	3
45	2	24	1	45	2
46	2	24	1	46	2
74	5	24	1	74	5
78	3	25	1	78	3
90	4	25	1	90	4
85	1	26	1	85	1
48	1	27	2	48	1
50	2	27	2	50	2
60	2	29	2	60	2
61	2	29	2	61	2
63	2	29	2	63	2
68	4	29	2	68	4
66	2	30	2	66	2
91	1	33	2	91	1

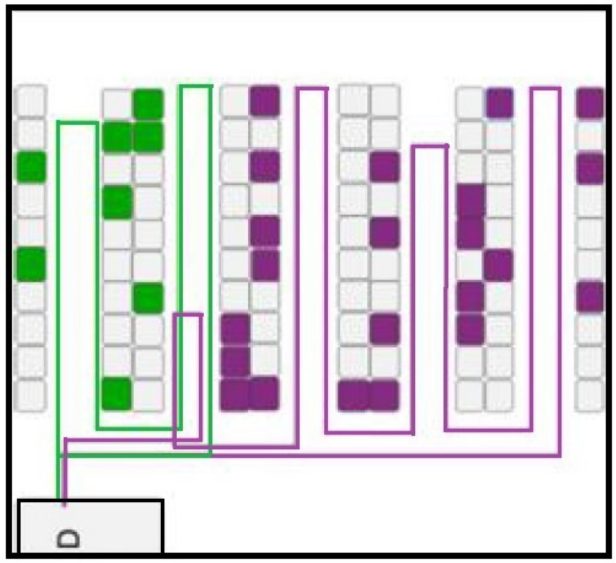

Fig. 4. Results of the third instance.

In the opposite case the VRP model provides the best minimization of the total distance, but with poor performance in batch formation, this result is because the vehicle capacity is not exploited properly.

Taking into account the costs associated to each procedure, it is more costly for the enterprise to have a bad performance in the batch formation. These events are the extra costs related to those items out of expiration time and those with items out of due date that are not moved on time in comparison with investing at improving the distance traveled to make a batch properly. This exercise provides a good approach to OBP problem where the batch formation and a convenient route to make a batch are considered. As it was stated before, the optimal applied method depends on the warehouse necessities.

CONCLUSIONS

It is important to have an efficient picking system in any company where a warehouse is related. The warehouse has a high impact in the supply chain. This project shows methods to improve the batch formation and the distance traveled within a warehouse by using the most common methods, where a distance reduction and an efficient batch formation was obtained. It can be observed possible benefits for an enterprise by applying these different methods.

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