The Application of Job-Shop Scheduling In Order Picking Problem A Case Study in Customer Distribution Warehouse Of DKSH

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Abstract. This paper proposes a method to solve Order Picking Problem based on Job-shop Scheduling. The method included the batching process needed to batch orders and then scheduling the batches by Job-shop scheduling. In both industry and the research literature, mixed integer programming (MIP) and constraint programming (CP) have often been the default approaches for solving scheduling problems. In this paper we presented and evaluated an MIP formulation and the standard CP formulation for the classical job shop scheduling problem (JSP). The study was conducted fast moving consumer products and large-scale warehouse. Results from a real application show that this method provides acceptable accuracy for practical purposes.

Keywords: Warehouse, Order picking, Order batching, Job-shop Scheduling, CPLEX.

1. INTRODUCTION

The role of distribution centers in a supply chain has become more and more important to the logistic industry. There has been much pressure on suppliers delivering goods to customers in an efficient way. A modern distribution center (DC), particularly, has more and more functions in the business environment. For example, customers can order some specified products, by telephone or internet and receive them within 24 hours. In order to achieve this policy, corporations need distribution centers with high efficient order picking processes in distribution warehouses.

Order picking, the process of order picking products from storage (or buffer areas) in response to a specific customer request, has been identified as the most labor-intensive operation in warehouses with manual systems, and a very capital intensive operation in automated systems (Goetschalckx and Ashayeri 1989, Drury 1988, Tompkins et al. 2003). It may consume about 60% of whole labor activities (Drury, 1989). Also according to Tompkins et al., the cost of order picking is evaluated to be as much as 55% of the total warehouse operating costs. For these reasons, warehousing managers should consider order picking with the highest-priority area for productivity improvements in warehouse management functions.

Warehouses nowadays have more functional than the time before. The previous role of warehousing is just to store or buffer products, but warehouses nowadays provide other value-added activities or services such as product consolidating, quality checking, cross-docking, final assembling, packaging, refurbishing (reverse logistics), information services, etc. So that warehouses are also becoming larger. In these large distribution warehouses, specifically at Customer Good distribution warehouse of DKSH, the daily pick volume is large and the available time window is short. In order to be more responsive to customers, the organization of order picking must be considered to improve.

DKSH's distribution with a large warehouse is hard to control and handle all the effects as well as the problem occurs if there is any change or improvement with the system.

DKSH use SAP Warehouse Management System to manage.But I see that, effective in Order Picking Problem is not good when they take a lot of time to pick up goods (12- 16 hours/days) and the pickup is mainly based on the experience of workers.

2. LITERATURE REVIEWS

Yukiyasu, Ikuo, Masahito and Masashi (2013) proposed a solution for dealing with the order picking problem with workers jamming restriction. They approached by transforming the order-picking problem to a job-shop problem. Moreover, they tested this model in real warehouse that large-scale with over 9000 orders. They applied Local Clustering Organization (LCO) to solve JSP.

They also will experiment on other conditions of logistic center model and find suitable number of workers on the variety condition in the future. Limitations of this article is only use order picking method, it increases time and travel distance of pickers.

According to an article of Ryan Key, Anurag Dasgupta, they present pick path problem in a warehouse. Generating pick paths involves solving two common place graph theory problems: the shortest path problem and the traveling salesperson problem(TSP). They define the shortest path to each of these vertices. After finding these shortest path, they treat the problem like a normal TSP.

In 2009, "Warehouse Order Picking Process" of Y. Merkuryev, A. Burinskiene and G. Merkuryeva analyses the influence of routing methods on distance of picker traveling in a wide-aisle warehouse. A simulation model was built to determine potential distance of traveling reduction. Through simulation, routing methods in a wide-aisle warehouse and other order picking process optimizations are analyzed. The presented results show that 60%of the picker travel distance can be reduced by using appropriate combination of optimization methods.

As reported by Sebastian Henn, So¨ren Koch, Harald Gerking and Gerhard Wa¨scher in article "A U-shaped layout for manual order-picking systems" in 2013, they present a new routing scheme for the order pickers who work in such storage, and they obtain an analytical expression for the expected tour length per picking order. By comparing this estimation with those of routing plan for traditional warehouse layouts, having some ways like the U-shaped form is regarded as one operating condition to allow more efficient warehouse.

The article "A Review Of Order Picking Improvement Methods" by Johan Oscar Ong, Don Thomas Joseph in 2014.This article helped me understand Concepts, Strategies and Policies in Order Picking Problem. Specifically: Firstly, Order Picking Strategies included Picker-to-stock, Stock-to-picker and fully automated system. I know that Stock-to-picker is best in 3 types because it is less investment compared to fully automated picking system and generally better productivity and accuracy compared to picker-to-stock strategy. Secondly, Storage assignment policies included 5 types. They are Random storage, closest open location storage, dedicated storage, class-based storage, and family grouping. Algorithms and methods are applied to this problem that are ELECTRE TRI method ABC analysis, several location sorting method, Cube-per-order index, interaction frequency heuristics. These methods are 11.25% improvement in productivity. Thirdly, Order batching is a way to improve picking productivity. I understand that this method helps picker to minimize travel distance or time. In addition, I also know that there are many approaches to this problem as Tabu search algorithm, Attribute-Based Hill Climber, savings algorithm C&, iterated local search, order batching procedure, indexed batching model. They help to reduce 5-15% total retrieval time. Finally, Order picking sequencing. This problem can be solved by the algorithm or heuristics as order-picking algorithm , dynamic programming method, Lin-Kernighan-Helsgaun heuristics, x-based coordinate heuristic and clustering based algorithm, polynomial algorithm, S-shaped heuristic, combined heuristics, a hybrid algorithm, particle swarm optimization (PSO) algorithm, ant colony optimization (ACO) algorithm, traveling salesman problem (TSP) heuristics. They help Picker to remove from 5 to 47% move distance. Summarize, according to the authors, they need improve "Order picking sequencing and routing heuristics" to improving order picking operations.

3. METHODOLOGY

To conduct this research, there were three steps as follows.

3.1 Collect Data

At first, the current layout drawing was retrieved from the company's layout (Manager, Distribution Center Operations) including dimensions of warehouse, position of depot, number of rack, number of location, number of aisle and distance between two consecutive location, consecutive aisle to create the distance matrix from/to for each position and all racks arrangement up to the first quarter of 2016.

Moreover, picking slips, picking policies, capacity of picker were created by interviewing with warehouse supervisors and also through the student's line walk observation. Finally, the operation orders in day 9/3/2016, number of items, bin locations were obtain from the warehouse manager.

Figure 1: Bin Locations

As the layout we can see 3 sub-warehouses or 3 area of order picking:

Non-food area has total 40 racks with 12 aisles: White area.

Food area has total 22 racks with 6 aisles: Yellow area

Air condition area has just 6 racks with 3 aisles: Blue area.

The layout also presents depot point where picker start to pick items in the order. (Notation:1).

In this drawing, Number 1-545: Bin Locations. Number 1: Depot.

Red numbers: Bins are empty.

The matrix distance between 545 bin locations showed in Figure 1.

3.2 Data Analysis

Different from other schedule and picking method approaches that mostly consider individuals, this paper aimed to find a schedule for pickers.Therefore, firstly, orders are combined together as long as the total distance among pickers is at least. Then the scheduling of pickers was conducted.

Table 1: Experiment condition of logistic center model and order-sheet data

Parameter	Value
The number of order sheet	586
The number of shelves	454
The number of kind of products	567
The speed of a worker[m/s]	1
Picking time/item[sec]	1

All sold items in all orders are listed in 9/3/2016.

It includes items, customer, bin location, quantity, weight, volume.

This model is the real logistic center and we use the real data for order sheets. Capability of this logistic center model and the order-sheet data are shown in Table 1.

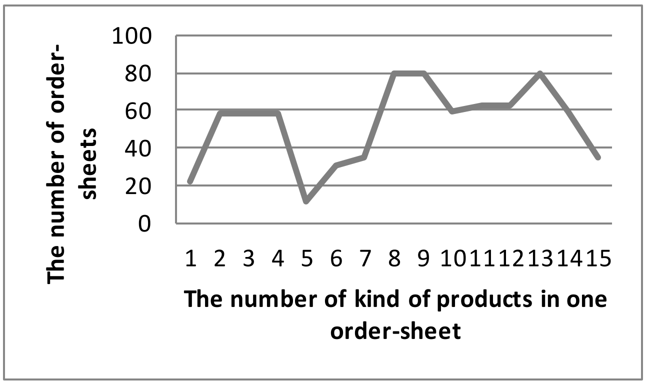

Figure 2: The number of kind of products in one order-sheet

Fig. 2 shows the distribution on the number of kinds of products in a single order sheet, that is what kind of products are ordered per one order. According to Fig. 7, the order sheet that specifies 8,9,13 kinds of product is mostly common.

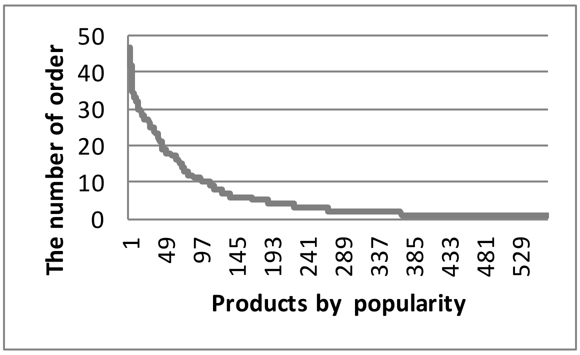

Figure 3: The number of kind of products and the number of ordered

Fig. 3 shows the distribution of the number of order on the product. Most products are ordered only once. Products which is ordered many times is fewer.

In Fig. 3, the most popular product is arranged in the origin and the most unpopular one is arranged to the most right hand side on the horizontal axis. Other products are arranged from the popular one to unpopular one.

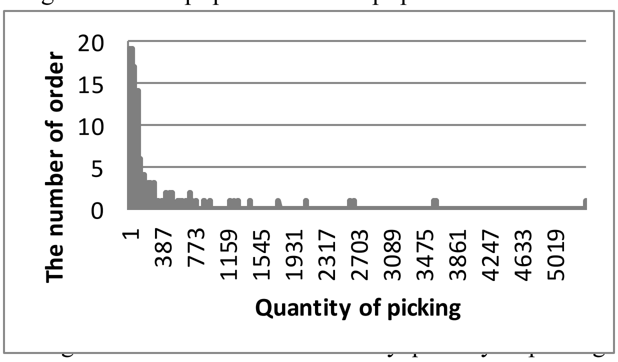

Fig. 4 shows the distribution on the number of order and the total picking times of products per one order. This chart shows most of order includes only one product for one kind of product per one order (the worker picks only one product for one kind of product).

These results show that the logistic center stores many kinds of product with a few numbers. However, there are some products, which are very popular and must keep them a very large number of them. In general, these product number distributions in the logistic center are often observed such as Amazon com. So, the logistic center needs a huge floor area but super markets.

3.3 Model Development

3.3.1 Relationship between Order Picking Problem (OPP) and Job-shop Scheduling Problem (JSSP)

3.3.2 Travel distance in DKSH's layout warehouse

Order-Picking	Job-Shop Problem
Order	Job
Shelf or Item	Machine
Sequence of picking products	Process sequence
Picking time	Machine time

The travel distance between any two items in traditional layout warehouse is defined as the length of the possible shortest path connecting these items.

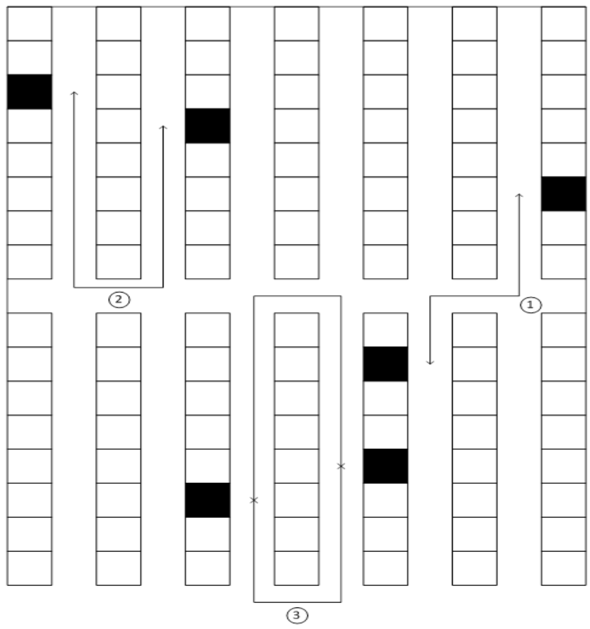

Figure 5: Illustrates all the connecting paths in each circumstance.

3.3.3 Batching Model

According to Gademann and Van de Vedle (2005)

$$\min \sum_{i \in I} d_i . x_i \quad (1)$$

s.t :

$$\sum_{j \in J} c_j . a_{ij} \le C, \forall i \in I \quad (2)$$

$$\sum_{i \in I} a_{ij} . x_i = 1, \forall j \in J \quad (3)$$

$$x_i \in \{0,1\}, \forall i \in I. \quad (4)$$

Parameters

J: the set of customer orders,

I: the set of feasible batches,

C: the capacity of the picking device,

cj: the capacity required for order j (j J),

di: the length of the picking tour in which all orders of a batch i are collected.

Variable

aij: binary variable, an order j is included in a batch i (aij = 1) or not (aij = 0),

xi: binary variable, if a batch i is chosen (xi = 1) or not (xi = 0).

Constraint (2): limits the volume of items of all orders in one batch.

The sets of constraints (3) and (4) ensure that a set of batches is chosen in a way that each customer order is included in exactly one of the chosen batches.

The OBP is known to be NP-hard (in the strong sense) if the number of customer orders per batch is larger than two (Gademann and van de Velde 2005). Numerical experiments based on the above-given model formulation (Henn et al. 2010) revealed that only small instances can be solved to optimality if all columns (batches) are generated in advance. This can be explained by the fact that the number of possible batches and, consequently, the number of binary variables increases exponentially with the number of customer ordersed under the paradigm of setting discrete decision variables (processing intervals and sequencing machines) with the objective function of minimizing Makespan.

Henn et al. (2010), e.g., report on problem instances consisting of 40 customer orders in which the number of feasible batches is larger than 350,000 for a warehouse with 900 storage locations. Henn et al. (2010) were only able to solve problem instances with at most 50 customer orders to optimality. For a large number of instances, the LP/IP solver was only able to generate feasible solutions but was unable to prove their optimality, since memory restrictions of the used PC were violated.

3.3.4 Travel Salesman Problem (TSP)

The length of the picking tour in which all orders of a batch is considered as a Travel Salesman Problem.

The Miller–Tucker–Zemlin (1960) formulation of classical TSP is given as following:

$$\min \sum_{i=1}^{n} \sum_{j \ne i, j=1}^{n} c_{ij} . x_{ij} \quad (1)$$

s.t :

$$\sum_{i=1, i \ne j}^{n} x_{ij} = 1 \quad \forall j \in A \quad (2)$$

$$\sum_{j=1, i \# j}^{n} x_{ij} = 1 \quad \forall i \in A \quad (3)$$

$$u_i - u_j + (n-1)x_{ij} \le n-2 \ \forall i \in A \setminus \{1\}, \forall j \in A \setminus \{1\}, \forall i \# j (4)$$

$$0 \le x_{ij} \le 1, x_{ij} \text{ interger}$$

Parameter:

cij: minimum distance from item i to item j

N={0,…,n}:the set of items

Variables:

xij: binary variable, equal 1 if path goes from item i(i belong to N) to item j(j belong to N), equal 0 otherwise

Constraint(2): each item be arrived at from exactly one other item

Constraint(3): from each item there is a departure to exactly one other item

Constraint (4): sub-tour elimination by ensuring that the position of location i is smaller than the position of location j if edge (i, j) is used.

However, because of this problem, Model MIP can only solve fewer than 40 items/cities. Therefore, I have used Tabu search algorithm to solve this problem.

Tabu search (Glover-1989) is a metaheuristic search method employing local search methods used for mathematical optimization.

Tabu-list contains moves which have been made in the recent past but are forbidden for a certain number of iterations.

The neighbors selected from swapping two adjacent elements.

Neighborhood: all schedules that can be obtained through adjacent pairwise

interchanges.

Tabu-list:

1) Select length of Tabu list: max numbers of pairs (2).

2) Put pairs of jobs (j, k) that were swapped within the last two moves

3.3.5 Job-shop Model

According to Disjunction Programming - Michael Pinedo (2012):

Min $C_{\max}$;

s.t :

-Makespan is the largest completion time:

$$C_{\max} = y_{ij} + p_{ij} \text{ for all } (i, j)$$

-Conjunctive arcs:

$$y_{hj} = y_{ij} + p_{ij} \text{ for all } (i, j) \rightarrow (h, j) \in A$$

-Disjunctive arcs :

$$y_{ij} \geq y_{ik} + p_{ik} \text{ or}$$

$$y_{ik} \geq y_{ij} + p_{ij} \text{ for all } (i, j) \text{ and } (i, k)\ i = 1...m$$

-Non-negative:

$$yij \geq 0 \text{ for all } (i, j) \in N$$

Parameters:

N: the set of all operations (i, j)

A: the set of all routing constraints (i, j) → (h, j)

pij: processing time of job j on machine j

Variables:

Cmax: Makespan

yij : the starting time of operation (i, j)

When I run this model by CPLEX, it only solve with 15 jobs and 15 machines. So, I used Constraint Programming to solve.

Constraint Programming (CP) is the study of computational systems based on constraints.

The CP model consists on running the standard algorithm of IBM for default job-shop scheduling problems.

This default model was conceived under the paradigm of setting discrete decision variables (processing intervals and sequencing machines) with the objective function of minimizing Make-span.

4. RESULT MODEL

In this chapter, some test problem and sample instance are solved to illustrate the Job-shop scheduling approach described in the previous chapter. I compare the make-span between DKSH's method and the proposed method, also travel distance between Order Picking method and Order Batching method.

The effectiveness and validity of the proposed method are examined by using the actual logistic center model and order sheets data.

As you see Figure 6, I compared travel distance of Order Batching method and Order Picking method. Order Batching method improved by 22% compared to Order Picking method.

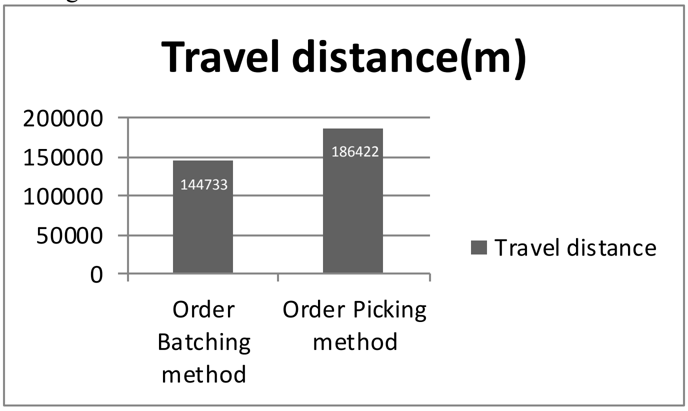

Figure 6: The travel distance of Order Batching method and Order Picking method

Result of Job-shop Model (MIP vs CP):

We converted OBP to JSSP by 2 method : Mix Interger Programming and Constraint Programming) with parameters:

Numbers of job: 58

Numbers of machine: 246

Processing time= Travelling time+ Picking time

Sequence Item=Travelling Salesman Problem

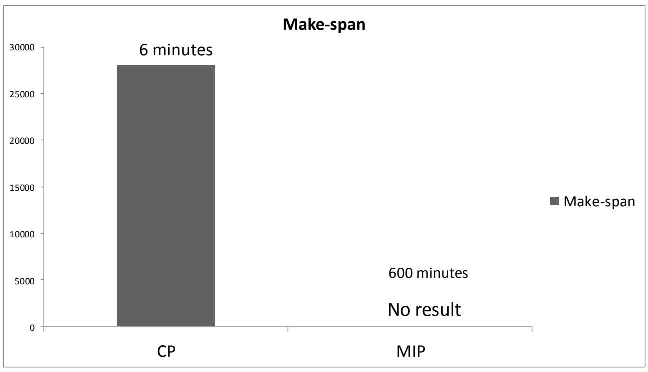

Figure 7: Completion time run MIP method and CP method

MIP method used Disjunction Programming and ran in 600 minutes but did not export to results.

Therefore, we use CP method and took 6 minutes for results.

Figure 8 shows statistics and Figure 9 shows Gantt chart of CP method.

Result Job-shop Model(CP):

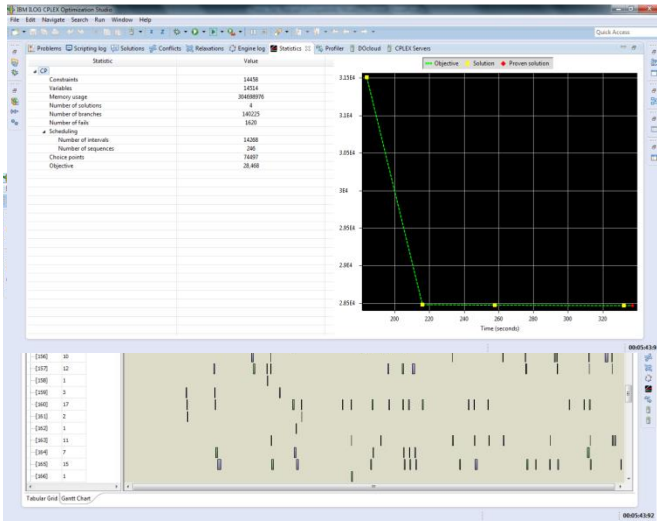

Figure 9: Gantt Chart of proposal method

In order to verify the efficiency, we compare the proposed method with First Come First Serve (FCFS) method or DKSH's method. FCFS is a rule to determine the workers picking priority and this rule is that workers arrived first can work preferentially on the shelves.

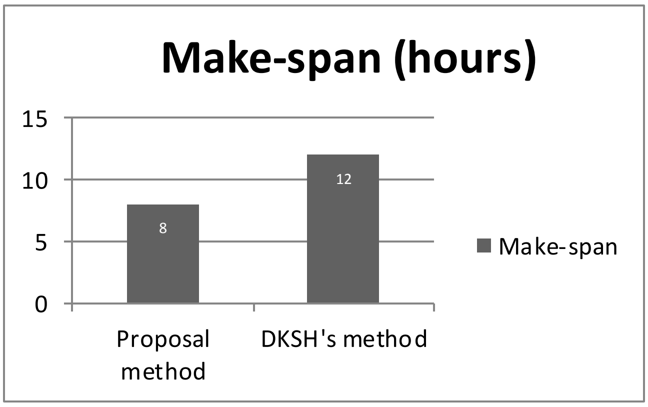

Figure 10: Shows make-span Proposal method vs DKSH's method.

A few jamming occurs for a few workers. It hardly make the waiting time on the shelves by DKSH's schedule. Furthermore, the make-span of proposed method is shorter 33% than method DKSH's in Fig.7

5. CONCLUSION

This study proposes the new method for an order picking problem. The proposed method can deal with the order-picking problem with workers jamming restrictions by transforming the order-picking problem to a job-shop problem.

In future work, I will make an experiment on other conditions of the logistic center model.

To solve large-scale order picking problem, I will use a heuristic to solve.

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