

## A Review on Quantitative Approaches for Dock Door Assignment in Cross-Docking

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**Abstract** - Cross docking is a relatively new technique in supply chain operations. It offers limited storage time to maximize the efficiency of goods transshipment. Efficient operation of a cross docking system requires an appropriate coordination of inbound and outbound flows, accurate planning and dynamic scheduling. The planning strategies at cross docking terminals, which are receiving growing attention today, are the truck-to-door assignment and destination to door assignment problems. This paper provides a comprehensive literature review of quantitative approaches in dock door assignment problems of cross docking planning. The contributions of this paper are to identify the gap of knowledge in operational levels mainly in dock door assignment and to point out the future research direction in cross docking.

**Keywords** - cross-docking; dock door assignment; quantitative approaches; mathematical model; optimization

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### I. INTRODUCTION

In contrast to traditional warehouse, a cross docking terminal is a distribution center which carries no or at least a reduced amount of stock. The idea of cross docking is to transfer shipments directly from incoming to outgoing trucks without storage in between. Usually shipments will spend less than 24 hours in cross docks or sometimes less than one hour. In a traditional model, warehouse maintains stock until they received the orders from customers, then the goods is picked, packed and shipped to them. When replenishment arrives at the warehouse, they are stored until the demand is identified. In a cross docking model, customer is known before the goods get to the warehouse and there is no need for storage. Besides, it also supports the shipments of full truck load (FTL) rather than Less Than Truck Load (LTL) [1]. As there is no or less inventory in storage due to direct transshipment, cross docking has been a potential logistic technique in order to reduce the inventory holding cost, order picking cost, transportation cost and delivery time [2].

Cross docking center serves as a consolidation platform of inbound products which offers short cycle times. The material arrived from supplier to cross docking terminal will be unloaded, sorted, consolidated and finally loaded onto the outgoing trucks which forward the shipments to the respective locations. As cross docking allows a consolidation of differently sized shipments for the same destination with full truck loads, the transportation cost will be more economical [2]. In general, the operation in cross docking terminal is divided into three main phases, which are unloading, sorting and loading processes. Once the

goods arrive at the arrival docks, they are scanned and verified to determine their specified destination. In some cross docking centers, the products are also weighted, sized and labeled at the shipping dock. Then, goods are taken by some material handling equipments, such as forklift operated by worker or some kind of automated conveyer belt, to the staging area. Here, the inbound goods are sorted, consolidated, and temporarily stored until the outbound shipment is completed. Then, the goods are forwarded to the shipping door for the next process, which is loading them into the outbound truck. Once an outbound truck has been completely loaded, the truck will move away from the terminal to allow another truck to dock for loading.

Cross docking can be applied for various purposes. For manufacturing, cross docking can be a potential platform for consolidating inbound supplies by respecting the Just in Time policy. For distribution, cross docking can be used to consolidate inbound goods from different suppliers which can be then delivered when the last inbound shipment is received. For transportation, it involves the consolidation of shipments from different suppliers which is normally in LTL batches in order to obtain economies of scale. Aside from that, for retail, cross docking is concerned with receiving goods from multiple suppliers, sorting them and shipping them to different stores. In fact, cross docking system has been successfully applied in many industries and several famous companies such as Wal-Mart, Home Depot, Costco, Canadian Tire, FedEx Freight, Toyota, Goodyear GB Ltd and Kodak Co. ([3], [4], [5]).

According to [6], the problem related to cross dock facilities can be divided into two categories, which are, a) problem that consider the facility as a node within a larger transportation network, and b) problem that focuses on the operation of the facility, which accounts for inbound doors, staging and outbound door. In general, the problem that considers the facility as a node deals with the routing of vehicles from or to the cross dock facility such as in [7], location and demand allocation to the cross dock facility [8] and design of the supply chain network problem as in [9]. For the latter problem, which focuses on the operations of the cross dock facility, there are two main issues, namely, the optimization of operations at inbound and outbound doors ([10], [11]) and optimization of operations within storage area of cross dock facility, as stated in ([6], [12]). Hence, effective planning strategies are very crucial to ensure an efficient operation at cross docking terminal. One of the planning strategies which are gaining more attention today is the truck-to-door assignment problems.

The objective of this paper is to review existing literature on solving dock door assignment problem in which the focus is on the models that consider quantitative approaches in solving the problem. Therefore, the contributions of this paper are to determine the gap of knowledge in operational levels mainly for dock door assignment problem in cross docking and to highlight the future research direction in this field. This literature review on dock door assignment is a part of our main study which concerns with the development of a mathematical model for truck scheduling and dock door assignment in cross docking problem.

## II. THE IMPORTANCE OF CROSS DOCK DOOR ASSIGNMENT PROBLEM

In cross docking, incoming trucks arrive at the receiving doors of terminal with various goods collected from multiple suppliers. Once a truck is assigned to an available inbound door, the goods are unloaded, sorted and moved onto the shipping door for delivery using the outbound truck. Due to the large amount of freight, dynamic nature of truck scheduling, flow of freight pattern in the cross dock center, the arrangement of inbound and outbound doors and the assignment of destinations to outbound door, cross dock door assignment has become a complex combinatorial optimization problem [13]. In fact, the performance of goods transshipment is influenced by the dock assignment. Good dock assignment can reduce dock delays. It can also minimize the operational time of transferring the items from dock to door. Finally, good dock assignment can reduce the operational cost especially the handling cost within the terminal including the worker and forklift equipment.

The main objective of the cross dock door assignment problem is to find an optimal arrangement of assigning the incoming/outgoing trucks to the inbound/outbound door position [14], and the most efficient assignment of destinations to each shipping door [15], so that the distance traveled by material handling equipment is minimized.

Since it determines the short and mid-term planning in the cross docking operation, dock door assignment has become a critical issue and studied by many researches. In this section, we discuss the literature on dock door assignment problem by identifying the objective of the study, quantitative modeling approach and solution technique of these past researches.

The cross dock door assignment problem is related to the dock door assignment problem, which was first formulated by [16]. They introduced a general bilinear model for assigning truck to door, where the objective is to minimize the travel distance between the incoming and outgoing trucks. They extended the study by proposing a solution for the bilinear programming model using Branch and Bound Algorithm [17]. Bartholdi III and Gue [18] conducted a study for minimizing the labor cost in cross docking terminal by constructing an efficient layout for door assignment. Three types of congestion typically experienced in cross docking terminal were discussed, which are interference among forklifts, dragline congestion and congested floor space. They modeled the problem based on statistical respective and solving it by using Simulated Annealing.

Bermudez and Cole [19] developed a genetic algorithm solution for assigning truck to strip and stack doors in break-bulk terminal. They tackled the problem as quadratic assignment problem with the objective to minimize the total travel distance, labor cost and cycle time. Meanwhile, Yu [20] studied three out of 32 models on cross docking to find the best truck spotting sequence for both receiving and shipping truck with the objective to minimize the total operation time. The author modeled the problem as Mixed Integer Programming and used four solutions approaches, which are Branch and Bound, Search Algorithm, Complete enumeration and heuristic to compare the performance. Oh et al. [15] proposed a non linear mathematical model for assigning the destination to the shipping door in cross docking system of mail distribution center. The main objective of their study is to improve operating efficiency by minimizing the travel distance of wheeled pallets in the centre. For the model, two solution methods, three phase heuristic procedure and genetic algorithm are developed. The door assignment problem tends to get more complicated when number of trucks exceeds number of docks available. Thus, Lim, Ma and Miao [21] developed an Integer Programming model with the consideration on time window and capacity constraint to solve this problem. The objective of the model is to minimize the total shipping distances for transferring items from inbound to outbound doors. They utilized Tabu Search and Genetic Algorithm to solve the model. In [22], these authors modified the model by changing the objective function, in which the objective is to minimize the total cost including sum of total dock operational cost and penalty cost for all unfulfilled shipment. The problem is solved using Genetic Algorithm. This study is continued whereby in [23], Tabu Search was combined with genetic Algorithm to find better solution using the same model.

As loading into outgoing trucks still remains a bottleneck process at distribution centre, Choi et al. [11] have proposed

an approach for assigning destination to shipping doors under fluctuating workload. The authors modeled the problem as non-linear programming model with two objectives; to minimize number of workers engaged in loading operation and to minimize the imbalanced ratio of workers. The problem is solved by using Genetic algorithm with line balancing heuristic. A study conducted by [24] is concerned with a model that allow the allocation of multiple trucks to the same gate in different time slot. They stated that the allocation of specific gate will affect the transportation volume for forklift vehicle inside the terminal, which depends on the destinations of the truck's load. Their approach is an extension of the model by [19], in which the goal is to find good solutions for larger instances. In fact, Bartz-Beielstein et al. [24] are the first who tackled the problem as evolutionary multi-objective optimization technique with two objectives that are to minimize the transportation volume inside the terminal and to minimize the waiting time for trucks between arrivals at terminal before being assigned to a gate. Heuristic method has been applied for finding the optimal solutions using the proposed model.

By considering the mix service mode type of cross docking, Shakeri et al. [5] put forward a generic mathematical model to address the issues of truck scheduling and truck to door assignment by employing a mixed integer programming approach. The authors applied the multiple stage hybrid flowshop to model the cross dock scheduling while for cross dock assignment, they used two-stage parallel-machine cross dock scheduling method of Song and Chen [25]). The main objective of the study of Shakeri et al. [5] is to minimize the total operational time (makespan) within the terminal. Another study carried out by [26] is similar to Choi et al. [11], but the study has considered an automated cross docking terminal as a case study. Cohen and Keren [14] suggest a new heuristic approach for assigning destination to shipping door. They analyzed the drawback of existing formulation in ([16], [17], [27]) and introduced a new approach for solving a small size problem of seven incoming trailers and a dock with 10 receiving doors and 10 shipping doors (overall 20 doors). Later on, with the belief that simulation can derive a more realistic objective function, Aickelin and Adewunmi [13] proposed two-fold solution called simulation optimization to study the cross dock assignment problem. The aim of their study was to develop a robust metaheuristic to find the optimal arrangement of inbound and outbound doors in the terminal and the most efficient assignment of destination to outbound doors such that the material handling cost can be reduced. Memetic algorithm was used for finding the optimal solution.

Yu and Egbelu [12] combined the problem on truck scheduling and the assignment of products to find the best truck docking. They developed three different solution approaches to solve the problem. First is a mathematical model to minimize the makespan. Second is the complete enumeration to generate all possible truck scheduling sequences and the last one is a heuristic algorithm to find the optimal value. Their work has been continued by Vahdani and Zandieh [28], who employed five metaheuristic approaches to obtain the much more faster solution for the

problem. These are genetic algorithm (GA), tabu search (TS), simulated annealing (SA), electromagnetism-like algorithm (EMA) and variable neighbourhood search (VNS). The study by [29] is different from another literature as outbound door assignment is fixed over period of time while inbound door assignment is solved on nightly basis. The study is concerned with assignment of trailers to doors such that the internal material handling effort is minimized. The problem is modeled as Rectilinear Quadratic Assignment (QAP) and solved by using simulated annealing based heuristic.

Recent study by [6] focused on operation of cross dock facility in assigning incoming and outgoing trucks to inbound and outbound doors. The authors considered the issue of handling time of inbound and outbound trucks as a function of door assignment of both set of trucks. Therefore, each outbound truck is assigned a number of forklifts equal to the number of pallets it carries. The problem is modeled as bi-objective model with two main objectives; to minimize the total service time for all trucks served at facility and to minimize the total storage time of commodities transferred from incoming to outgoing trucks. For this study, a Multi Objective Memetic Algorithm (MOMA) is proposed to solve the model.

In addition, Berghman, Leus and Spieksma [30] explored limits of instances sizes that can be solved to guaranteed optimality within acceptable running time using the integer programming model. They modeled the problem of dock assignment as three-stage flexible flowshop where first and third stage share the same identical parallel machine while for the second stage consist of different set of identical parallel machine. They compared various mathematical formulations for parallel-machine scheduling problem pertaining to dock assignment problem, which are the assignment-based formulation, flow formulation and time-indexed formulation. They found that the time-indexed formulation performed significantly better than the other formulations. Table 1 presents the summary of past studies along with the quantitative approaches used in solving the dock door assignment problem.

#### IV. REFERENCE MODEL

The model by Tsui and Chang [16] is by far the most cited model for cross dock door assignment. This model can be represented by the following formulation.

$$\text{Minimize } \sum_j \sum_i \sum_n \sum_m w_{mn} d_{ij} x_{mi} y_{nj}$$

subject to:

$$\sum_m x_{mi} = 1 \quad \text{for } i = 1, 2, \dots, I \quad (1)$$

$$\sum_i x_{mi} = 1 \quad \text{for } m = 1, 2, \dots, M \quad (2)$$

$$\sum_n y_{nj} = 1 \quad \text{for } j = 1, 2, \dots, J \quad (3)$$

$$\sum_j y_{nj} = 1 \quad \text{for } n = 1, 2, \dots, N \quad (4)$$

$$X_{mi} = 0 \quad \text{for all } m, i$$

$$y_{nj} = 0 \text{ for all } n, j$$

where,  $I$  = receiving door,  $J$  = shipping door,  $M$  = origins,  $N$  = destinations,  $d_{ij}$  = distance between receiving door  $i$  and shipping door  $j$ ,  $x_{mi} = 1$  if origin  $m$  is assigned to

receiving door  $i$ ,  $x_{mi} = 0$  otherwise,  $y_{nj} = 1$  if destination  $n$  is assigned to shipping door  $j$ ,  $y_{nj} = 0$  otherwise.

TABLE I  
SUMMARY OF QUANTITATIVE APPROACHES FOR DOCK DOOR ASSIGNMENT

Author	LP	IP	NLP	MIP	MOP	QAP	SIM	STAT	FM	EA	HEU	MHEU
Tsui & Chang (1990)	√											
Tsui & Chang (1992)	√									√		
Bartholdi III & Gue (2000)								√				√
Bermudez & Cole (2001)						√						√
Yu (2002)				√						√	√	
Oh et al. (2006)			√								√	√
Lim et al. (2006a)		√										√
Lim et al. (2006b)		√										√
Miao et al. (2009)		√										√
Choi et al. (2006)			√								√	√
Bartz-Beielstein et al. (2006)					√						√	
Shakeri et al. (2008)				√					√			
Ko et al. (2008)			√								√	
Cohen & Keren (2008)											√	
Aickelin & Adewunmi (2008)							√					√
Yu & Egbelu (2008)				√							√	
Vahdani & Zandieh (2010)												√
Bozer & Carlo (2008)						√						√
Goliasa et al. (2010)					√							√
Leus & Spieksma (2010)									√			

**Note:** LP – Linear Programming, IP – Integer Programming, NLP – Non linear Programming, MIP – Mixed Integer Programming, MOP – Multi Objective Programming, QAP – Quadratic Assignment Programming, SIM – Simulation, STAT – Statistics, FM- Flowshop Model, EA – Exact Algorithm, HEU – Heuristics, MHEU – Metaheuristics.

Constraint (1) guarantees that each receiving door is assigned only one region. Constraint (2) guarantees that each origin is assigned only one receiving door. Constraint (3) guarantees that each shipping door is assigned only one destination. Finally, constraint (4) guarantees that each destination is assigned only one shipping door

## V. DISCUSSION AND FUTURE RESEARCH

Based on literature review, various quantitative models have been developed by researchers for solving dock door assignment problem. Most of the studies considered minimizing the total operational time or makespan as the main objective of their proposed models. From the review, there are two activities in the cross dock terminal which really need detailed planning and strategies for efficient assignment. First, is how to assign the trucks to the available doors once they arrived to the yard. Where, when and which trucks and doors should be assigned will

determine the efficiency of terminal operations. Second is how to assign the destination to shipping door, so that the cost of material handling devices inside the terminal can be minimized. This is largely influenced by the dock door assignment. Thus far, only one model has been proposed concerning the layout of the cross dock facility. However, this assignment model did not consider the layout inside the terminal such as the distance of the staging and temporary area to the door. Thus, it can be concluded that most of the studies seemed to neglect the congestion issue inside the cross dock terminal itself. As the size of freight become larger in the terminal, more goods need to be handled and the handling process will require a faster manoeuvre of forklifts. Consequently, the usages of forklift will be multiplied and speedy movement is required and this may create congestion within the terminal. Hence, it will be a valuable contribution to investigate a more efficient assignment procedure for conducting this kind of material handling equipments.

Based on the review, there is only one study that combined the problem of cross dock scheduling and truck-to-door assignment and the problem was solved using the flowshop model. Complexity is anticipated in finding an optimal solution if these two problems are solved together. However, this might be an opportunity for future research, where new mathematical models could be developed. Furthermore, most studies assumed there is only one receiving and one shipping door. But, in real applications, there are multiple numbers of receiving and shipping doors at the distribution center. Thus, the assignment of trucks to the multiple numbers of receiving and shipping doors for cross docking will be more challenging prospective studies to embark on. Many studies focused on truck assignment and assignment of destination to shipping door. However, research that focuses on the product assignment problem is still lacking despite the fact that the flow of freight/products inside the terminal will also affect the handling time of operations.

## VI. CONCLUSION

This paper presents a review on quantitative models of dock door assignment problem in cross docking operations. The purpose of this review is to identify the existing studies pertaining to this problem and analyze the gap of knowledge in studies conducted. Besides that, the aim of this review is also to provide some ideas or starting points for future research concerning the dock door assignment.

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