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Simultaneous dock assignment and sequencing of inbound trucks under a fixed outbound truck schedule in multi-door cross docking operations

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ABSTRACT

This paper studies the simultaneous dock assignment and sequencing of inbound trucks for a multi-door cross docking operation with the objective to minimize total weighted tardiness, under a fixed outbound truck departure schedule. The problem is newly formulated and solved by six different metaheuristic algorithms, which include simulated annealing, tabu search, ant colony optimization, differential evolution, and two hybrid differential-evolution algorithms. To evaluate the total weighted tardiness associated with any given inbound-truck sequence and dock assignment, an operational policy is developed. This policy is employed by every metaheuristic algorithm in searching for the optimal dock assignment and sequence. Each metaheuristic algorithm is tested with 40 problems. The major conclusions are: (1) metaheuristic is generally an effective optimization method for the subject problem; (2) population based metaheuristic algorithms are generally more effective than projection based metaheuristic algorithms; (3) proper selection of algorithmic parameters is important and more critical for projection based metaheuristic algorithms than population based algorithms; (4) the two best algorithms are ant colony optimization and hybrid differential evolution 2; among them, ACO takes less time than hybrid 2 and thus can be declared the best among all the six metaheuristic algorithms tested.

1. Introduction

A well-designed and well-executed distribution network system constitutes a very important part of an entire supply chain system in order to supply products to customers quickly in an increasingly more competitive market. In any distribution network system, warehouses or distribution centers are key components. The operation of a warehouse or distribution center typically consists of five basic functions, which include receiving, sorting, storing, retrieving, and shipping. Improving the operational efficiency of a warehouse or distribution center has been and is still a top priority on any company's agenda. Of particular interest in this paper is the concept of cross docking that has the potential to do away with storing and retrieving, two most expensive functions in operating a warehouse or distribution center. A distribution center/system with minimal storage and retrieval functions is known as a cross docking center/system.

In a cross docking system, items move directly from receiving dock to shipping dock, without being stored in the warehouse or distribution center. Fig. 1 shows the flow of materials in a typical cross docking operation. As shown in the figure, the cross docking system generally operates as follows:

- Products (in packages, boxes, cartons, etc.) arrive at the cross docking system and are scanned and verified at the receiving docks. In some cross docking systems products are also weighed, sized and labeled at the receiving dock.
- Products are placed on the sortation system, in which items are sorted by destinations.
- Products are moved to the proper location on the shipping docks and leave the cross docking center.

Despite its potential, cross docking centers are not anticipated to replace all distribution centers any time soon. In general, cross docking works best for big companies such as Walmart which distribute large volumes of merchandise and/or serve a large number of stores. Cross docking systems often handle a high volume of items in a short amount of time. The advantages of cross docking systems include increased inventory turnover, hence reduced inventory,

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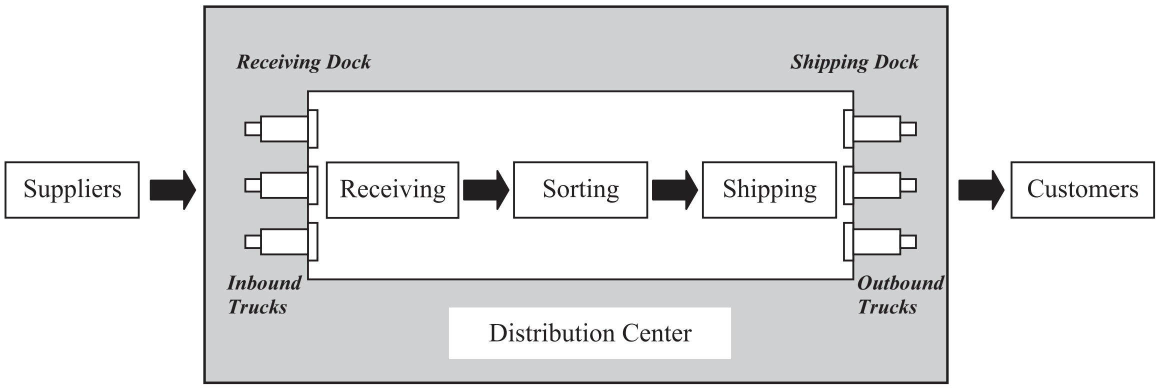

Fig. 1. Typical flow in a cross docking system.

increased customer responsiveness, and better control of the distribution operation.

Research focused on improving the efficiency of cross docking operation is still relatively few compared to those directed at traditional distribution center operations. However, there have been increased activities. Several cross docking related topics have been investigated, which include simulation modeling (Rohrer, 1995), system design (Apte and Viswanathan, 2000; Jayaraman and Ross, 2003; Sung and Song, 2003; Bartholdi and Gue, 2004; Sung and Yang, 2008), location and layout (Hauser and Chung, 2006; Vis and Roodbergen, 2008; Ross and Jayaraman, 2008), distribution planning (Chen et al., 2006; Musa et al., 2010), vehicle routing (Lee et al., 2006; Wen et al., 2009), dock door assignment (Oh et al., 2006), and truck sequencing/scheduling (Boysen and Fliedner, 2010). Truck sequencing is the subject of this paper and a more detailed review follows.

The efficient operation of a cross-docking center essentially involves the best coordination of inbound and outbound trucks. The truck sequencing/scheduling problem has been the focus of a number of studies. The bulk of previous studies consider only single receiving door and single shipping door (Yu and Egbelu, 2008; Maknoon and Baptiste, 2009; Boysen et al., 2010; Forouharfard and Zandieh, 2010; Soltani and Sadjadi, 2010; Vahdani and Zandieh, 2010; Arabani et al., 2011; Liao et al., 2012). Though the above-mentioned studies offer insights into cross docking operations, they are inapplicable to real world because a cross docking center with single receiving door and single shipping door is rare. Studies that consider multiple receiving docks and multiple shipping docks are thus necessary and there have been a few studies, as reviewed below.

Li et al. (2004) formulated the multi-door cross docking scheduling problem as a two-stage parallel machine problem with earliness and tardiness and proposed two genetic algorithm-based approaches for its solution with the objective to minimize the total penalty of weighted earliness and weighted tardiness. Following the same idea, Chen and Song (2009) formulated a mixed integer programming problem with the objective to minimize makespan and developed four heuristics for its solution. However, no metaheuristc algorithm was employed in their study.

McWilliams and his coworkers conducted three studies devoted to the parcel hub scheduling problem (PHSP) involving the scheduling of a set of inbound trailers loaded with a batch of heterogeneous parcels to a set of shipping docks, with the objective of minimizing the time span of the transfer operation. In the first installment, McWilliams et al. (2005) proposed a simulation based scheduling algorithm utilizing a genetic algorithm (GA) to guide the search. To reduce the demand for simulation evaluations, McWilliams (2009) proposed a 0–1 minimax programming model resembling a multi-knapsack problem, and used a genetic algorithm to solve the large-scale PHSP. In the third installment, McWilliams (2010) developed local search and simulated annealing algorithms and showed that both algorithms outperformed GA.

Boysen (2010) considered a special truck-scheduling problem with two major characteristics, i.e., zero temporary storage typical for products such as frozen foods and pre-distribution of goods from inbound trucks to outbound trucks, associated with operating a multi-door cross docking center. Three different objectives, i.e., overall flow time, the total processing time, and the total tardiness, were alternatively used. For the solution of each single objective, he presented two approaches, i.e., dynamic programming and simulated annealing. Zhang et al. (2010) studied the scheduling of inbound trucks and outbound trucks at a multi-door cross dock facility. They built a multi-objective mixed integer model. For solving each objective, a restriction-approximation approach was developed. Finally, 45 combinations of weights were applied to solve 45 single objective optimization problems and seven Pareto front points were identified at the end. However, no metaheuristic algorithm was employed in their study. Without exception, all of the above mentioned multi-door cross-docking studies assume zero temporary storage.

To the best of our knowledge, the recent paper of Alpan et al. (2011) is the only one that considers cross docking with multiple doors and temporary storage. They proposed a bounded dynamic programming approach to determine the optimal sequence of the set of outbound trucks such that the total cost is minimized, given a known inbound truck sequence. Our study is motivated by the review of Boysen and Fliedner (2010), in which they identified the lack of multi-door cross docking studies that consider the case where all outbound trucks are previously fixed concerning the destination they serve, the point in time they leave the terminal and the dock doors they are served at. Our study differs from most previous studies (except Alpan et al.) in allowing temporary storage. It differs from Alpan et al. in focusing on inbound truck sequencing rather than on outbound truck sequencing and in considering sequencing and dock assignment simultaneously rather than sequencing or dock assignment only. The new contributions of this study include (i) formulating a new problem associated with a multi-door cross docking system, (ii) proposing a policy to operate the system, (iii) developing six metaheuristic algorithms to find the optimal solution for operating the system, and (iv) evaluating the relative performance of all six algorithms.

The remainder of the paper is organized as follows. Section 2 describes the subject optimization problem and a proposed operating policy. Section 3 describes the six metaheuristic algorithms developed to solve the problem. Forty test problems and test results are presented in Section 4, followed by the Discussion section. Finally, the paper is concluded by highlighting major research findings and identifying topics for future research.