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Genetic algorithms for door-assigning and sequencing of trucks at distribution centers for the improvement of operational performance ☆

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ABSTRACT

In a supply chain, cross docking is one of the most innovative systems for improving the operational performance at distribution centers. By utilizing this cross docking system, products are delivered to the distribution center via inbound trucks and immediately sorted out. Then, products are shipped to customers via outbound trucks and thus, no inventory remains at the distribution center. In this paper, we consider the scheduling problem of inbound and outbound trucks at distribution centers. The aim is to maximize the number of products that are able to ship within a given working horizon at these centers. In this paper, a mathematical model for an optimal solution is derived and intelligent genetic algorithms are proposed. The performances of the genetic algorithms are evaluated using several randomly generated examples.

1. Introduction

Many logistics companies are trying to develop new distribution strategies in order to efficiently operate their supply chains. The endeavor to find new strategies is a consequence of customers ordering small quantities of various products but at the same time, demanding a more accurate and timely delivery. One innovative strategy to minimize unnecessary inventory and enhance the customer service level is cross docking (Apte & Viswanathan, 2000). Distribution centers utilizing the cross docking system becomes the consolidation point within the supply chain. Products are delivered to the center via inbound trucks. Following the delivery, products are immediately sorted out, routed, and loaded back to outbound trucks for timely delivery to customers. Thus, no inventory remains at the center. Cross docking system possesses potential benefits which will reduce cost and also, improve efficiency, by eliminating storing and retrieving processes of the traditional distribution center.

Problems with operations management at distribution centers with cross docking systems are discussed in various research studies. Apte and Viswanathan (2000) offer a framework for understanding and designing cross docking systems and furthermore, discuss the techniques for improving the overall efficiencies of logistics and distribution networks. Bartholdi and Gue (2004) explore the best shape for a cross docking system. They conclude that the best shape depends on the size of the facility and the pattern of freight flows within it. Tsui and Chang (1990, 1992) study the process of door assignment at destinations. They solve the issue as a quadratic assignment problem, which minimizes the shipment flows between doors. Miao, Lim, and Ma (2009) consider a truck dock assignment problem with an operational time constant for cross docking systems, assuming that the number of trucks exceeds the number of docks available. Miao et al. (2009) combine two objective functions into their model: the sum of the total dock operation cost and the penalty cost for all unfulfilled shipments. Along with the above studies, various researches have been done on this door assignment problem (Bartholdi & Gue, 2000; Bozer & Carlo, 2008; Gue, 1999; Oh, Hwang, Cha, & Lee, 2006). If the problem of assigning doors at destinations is solved in an early stage, the short-term truck scheduling problem can also be solved in the subsequent stage.

At distribution centers with cross docking systems, inbound and outbound truck scheduling problems become crucial operational management problems. Li, Lim, and Rodrigues (2004) regard the cross docking scheduling problem as a machine scheduling problem. Hence, to minimize this concern, they aim to minimize storage and order picking activity through the use of JIT scheduling. McWilliams, Stanfield, and Geiger (2005) cover a specific truck scheduling problem at a parcel hub, which is solved by a simulation-based optimization approach. Yu and Egbelu (2008), Vahdani and Zandieh (2010), Boloori Arabani, Fatemi Ghomi, and Zandieh (2011), and Soltani and Sadjadi (2010) consider an independent

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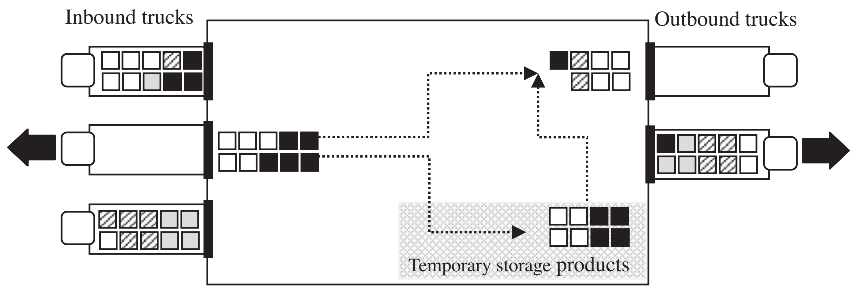

Fig. 1. Flow of products in a multi-door cross docking system.

sequencing problem of the inbound and outbound trucks in a specialized cross docking system containing a conveyor belt system, where a single inbound door serves a single outbound door. Yu and Egbelu (2008) develop a mixed integer programming model to minimize makespan, and propose a priority rule based heuristic. This heuristic is evaluated against a complete enumeration of all inbound and outbound sequences, with test instances up to 12 trucks (6 inbound and 6 outbound). Vahdani and Zandieh (2010) propose solution methods based on five meta-heuristics: genetic algorithm, tabu search, simulated annealing, electromagnetism-like algorithm, and variable neighborhood search. A lower bound is presented to evaluate the resultant solutions of meta-heuristic methods. Boloori Arabani et al. (2011) also propose solution methods based on five meta-heuristics: genetic algorithm, tabu search, particle swarm optimization, ant colony optimization, and differential evolution (DE). Two hybrid meta-heuristics are proposed by Soltani and Sadjadi (2010) to solve the specialized cross docking system containing a conveyor belt system. Boysen, Fliedner, and Scholl (2010) also analyze the sequencing problem of inbound and outbound trucks with a single inbound and a single outbound door. However, they choose a more aggregate view, simplifying the detailed handling times of products. Boysen et al. (2010) develop a decomposition approach which is based on a partial fixation of the problem in order to minimize makespan. For a given inbound (outbound) sequence of trucks, the (nearly) optimal outbound (inbound) sequence is determined by a suited dynamic programming approach, as well as some heuristic procedures. Boysen (2010) studies a special truck scheduling problem arising in the zero-inventory cross docks of the food industry, where strict cooling requirements forbid intermediate storage inside the terminal. The operational objective in this study is to minimize flow time, processing time, and tardiness of outbound trucks. He presents an exact dynamic programming approach, extended with lower and upper bounds (also known as bounded dynamic programming), and a heuristic simulated annealing approach. Boysen and Fliedner (2010) classify the deterministic truck scheduling problems in a cross docking system. With the help of this classification, existing studies are reviewed and future research needs are identified. Moreover, they represent a yet, unexplored class of truck scheduling problems, which are highly relevant in the real-world distribution networks.

To improve the operational performance at distribution centers, control policies maximizing the throughput in a given working horizon are significant (Gallien & Weber, 2010). Working horizon is a continuing interval for internal working processes at distribution centers, such as unloading, moving, sorting, and loading. This paper examines the scheduling problem of inbound and outbound trucks at distribution centers with cross docking systems so that the number of products capable of shipping is maximized within a given working horizon. If certain products are not shipped to their scheduled outbound trucks within the working horizon, then they are temporarily stored at the center and shipped during the next working horizon.

The distribution center examined in this paper possesses several characteristics. First, the receiving dock (where products are unloaded from inbound trucks) and the shipping dock (where products are loaded to outbound trucks) are separated from one another. Also, these docks have multiple doors. Inbound trucks enter, successively, through predetermined doors at the receiving dock and unload their products. Unloaded products are transported to the shipping dock and temporarily stored at the dock until the appropriate outbound trucks arrive. Outbound trucks enter via predetermined doors at the shipping dock and load their products. Once the trucks arrive at the docks, both inbound and outbound trucks must remain at the docks until all the unloading/loading activities are complete. When the task is finished, the trucks must leave immediately. All products unloaded from the inbound trucks should be transferred only after the unloading process is completely settled. On the other hand, the loading process for an outbound truck should commence only after preparing all of the required products. Fig. 1 shows the flow of products in the multi-door cross docking system.

The objective of this paper is to find the most effective schedules for inbound and outbound trucks in the cross docking system so that the number of products shipped during a working horizon is maximized. Truck scheduling is comprised of assigning each inbound and outbound truck to a door at the dock, as well as determining the docking sequences for all trucks at each door. A mathematical model for finding the optimal solution is derived in Section 2. The mathematical model can be solved by an optimization tool, such as the CPLEX. However, the tool does not yield a solution for problems over 6 inbound trucks and 6 outbound trucks due to the long computational time. Thus, in Section 3, we propose genetic algorithms (GAs) with three different types of chromosomes to deal with the truck scheduling problem. The GAs are as such: GA with special character (GA_SC), GA with double string chromosomes (GA_DS), and intelligent GA with dispatching rule (GA_DR). In Section 4, the performances of the GAs are evaluated through computational experiments. Finally, in Section 5, summary and further research areas are noted.

2. Mathematical model

The mixed integer programming model is derived to decide *where* and *when* inbound and outbound trucks should be processed at distribution centers with multi-door cross docking systems. Product assignments from inbound trucks to outbound trucks are also determined simultaneously, along with door assignments and docking sequences of inbound and outbound trucks.