Expert Systems with Applications 41 (2014) 16–22

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

Applying an adaptive tabu search algorithm to optimize truck-dock assignment in the crossdock management system

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ARTICLE INFO

Keywords:
Tabu search
Dock assignment
Artificial intelligence
Crossdock management system

ABSTRACT

Different from warehouse, crossdock is considered as a "JIT" technique in logistics and supply chain management (LSCM), which is usually a short period of time to store cargos. Since cargos transported to a crossdock by inbound trucks are immediately sorted out, repackaged, routed and loaded into outbound trucks and then delivered to customers within one day, one of the key issues to operate crossdock successfully is to develop an efficient truck-dock assignment module in the crossdock management system so that all the cargos can be delivered to customers on time. In this paper, we propose an adaptive tabu search (ATS) algorithm as an artificial intelligence (AI) tool to optimize the truck-dock assignment problem within a crossdock in a very efficient way, and computational experiments are conducted, showing that our approach dominates the CPLEX Solver in both effectiveness and efficiency.

1. Introduction

Crossdock is a material handling and distribution point in logistic network, in which items move directly from receiving dock to shipping dock without being stored for a long period, and has been highly emphasized by researchers and companies recently in warehouse management. The activities at crossdocks include assigning trucks to docks, sorting, scanning, repacking, routing and loading items shipped from inbound trucks to outbound trucks, as well as temporary inventory managing (Bartholdi & Gue, 2002; Boysen & Fliedner, 2010; Lim, Miao, Rodrigues, & Xu, 2005). One of the key decisions is the dock assignment for both inbound and outbound trucks. Dock assignment affects the performance of transshipment network, efficient dock assignment can be helpful to reduce shipment delays, operational times in crossdock and cost including operational cost for transferring, sorting and repacking (Acar, Yalcin, & Yankov, 2012; Alpan, Larbi, & Penz, 2011a, Alpan, Ladier, Larbi, & Penz, 2011b; Boloori Arabani, Fatemi Ghomi, & Zandieh, 2011; Boysen, 2010; Konur & Golias, 2013; Lee, Kim, & Joo, 2012; Liao, Egbelu, & Chang, 2013; Miao, Lim, & Ma, 2009; Vahdani & Zandieh, 2010; Yu & Egbelu, 2008).

Up to now, more and more research papers deal with the short-term scheduling problems which continuously arise during the daily operations of crossdock terminals. Lim et al. (2005) worked on various transshipment problems in a crossdock distribution network, and they found that well-scheduled trucks assignment can help to reduce the transportation time and inventory holding time, correspondingly reduce the transportation costed as well as inventory cost by consolidation. Bartholdi and Gue (2002) examined minimizing labor costs in freight terminals by properly assigning incoming and outgoing trailers to doors with respect of types of congestion, however, they did not address actual dock assignments to arriving vehicles when considering the time window of trucks. Yu and Egbelu (2008) studied a crossdock system with unlimited temporary storage. They investigated to find the best truck docking or scheduling sequence for both inbound and outbound trucks to minimize total operation time when a temporary storage buffer to hold items temporarily is located at the shipping dock, but they left out various important issues in real application such as crossdock physical layout, warehouse capacity, and arrival/departure schedules of vehicles. Based on the strategies proposed by Yu and Egbelu (2008) and Vahdani and Zandieh (2010) applied other heuristic methods, including genetic algorithm, tabu search, population based simulated annealing with diversification, and variable neighborhood search algorithm, to solve the same problem in Yu and Egbelu (2008), and proved the robustness of each proposed heuristics by numerous computational experiments. Miao et al. (2009) provided scheduling procedures adopted from gate assignment in airports, where trucks are assumed to have given service time windows, and they proved the problem is $\mathcal{NP}$-hard, therefore two kinds of meta-heuristics including genetic algorithm and tabu search were proposed to find an optimal solution. Boysen (2010) treated a special truck scheduling problem arising in the zero-inventory crossdocks of the food industry to minimize time makespan including the flow time, processing time and tardiness of outbound trucks. Boloori Arabani et al. (2011) proposed genetic algorithm, tabu search, particle

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http://dx.doi.org/10.1016/j.eswa.2013.07.007

swarm optimization and so on to find the best sequence of inbound and outbound trucks in order to minimize the total operation time. Lee et al. (2012) aimed to maximize the amount of products that are able to ship within a given time horizon and developed intelligent genetic algorithms to optimize door-assigning and sequencing of trucks in crossdocks. Konur and Golias (2013) studied a crossdock truck scheduling problem by formulating a bi-level optimization problem and developed a genetic algorithm to solve it. Alpan et al. (2011a) proposed a bounded dynamic programming approach to schedule inbound and outbound trailers in a multiple receiving and shipping door cross dock environment. In their another paper, Alpan et al. (2011b) developed several heuristics to find the best schedule in order to minimize the sum of inventory holding and truck replacement costs. Liao et al. (2013) proposed six meta-heuristic algorithms, including simulated annealing, tabu search, ant colony optimization and so on, to minimize total weighted tardiness for the dock assignment and sequencing of inbound trucks in a crossdock. Acar et al. (2012) introduced a mixed integer quadratic model for the problem which considered variability of truck arrival and service time. We refer readers to Boysen and Fliedner (2010) for thorough and excellent literature reviews of crossdock scheduling.

Artificial intelligence tools are widely applied to the dock assignment problem in crossdocks, because as the increasing of problem scale, traditional methods or softwares cannot find the best solution effectively. Besides those literatures mentioned above, there are a lot of papers which applied artificial intelligence tools such as genetic algorithm, tabu search, simulated annealing and so on, to the other optimization problems such as inventory routing problem, production planning problem, network design problem, vehicle routing problem, and so on. McWilliams, Stanfield, and Geiger (2005) treated a different truck scheduling problem arising from freight consolidation terminals in the parcel delivery industry, where the movement of goods inside the terminal is conducted by a convey or belt system, and proposed a simulation-based scheduling algorithm that used a genetic algorithm to drive the search for new solutions. Lin, Yu, and Lu (2011) studied the truck and trailer routing problem with time windows and proposed a simulated annealing heuristic which can obtain consistent quality solutions. In this paper, we design a new tabu search algorithm to resolve proposed truck-dock assignment problem in a crossdock since tabu search proposed by Glover and Laguna (1998) is known as one of the powerful artificial intelligence tools to solve $\mathcal{NP}$-hard problems. Ramezanian, Rahmani, and Barzinpour (2012) considered general two-phase aggregate production planning problem which is $\mathcal{NP}$-hard and implemented tabu search algorithm to produce good-quality solutions. Li, Leung, and Tian (2012) developed a multistart adaptive memory-based tabu search algorithm to solve the heterogeneous fixed fleet open vehicle routing problem (HFFOVRP), and computational experiments showed that this modified tabu search algorithm has efficiency and effectiveness. Tarantilis, Stavropoulou, and Repoussis (2012) studied another vehicle routing problem called consistent vehicle routing problem (ConVRP) and solved it by a template-based tabu search algorithm. Moreover, Liao, Lin, and Shih (2010) integrated crossdock into vehicle routing problem and applied tabu search algorithm to determine the number of vehicles and a set of vehicle schedules with a minimum total cost including operation cost and transportation cost.

In this paper, we extend the problem proposed by Miao et al. (2009), and take consideration of time windows for both inbound and outbound trucks in a transshipment network through crossdocks where the number of trucks exceeds the number of docks available, of which the objective is to minimize the total costs including operational cost of the cargo shipment and penalty cost of unfulfilled shipments. And we formulate this problem into a $0-1$ integer programming model. Since this kind of truck-dock assignment problem is $\mathcal{NP}$-hard, meta-heuristic should be a good approach to solve it. Adaptive tabu search (ATS) is proposed and developed for conducting computational experiments on test sets, and the results compared with CPLEX Solver 11.0 show that our algorithm dominates the CPLEX Solver in most of all test cases.

This paper is organized as follows: in the next section, we give an IP model of the problem. Adaptive tabu search is proposed and developed in Section 3. We provide computational results in Section 4. In Section 5, we summarize our findings and suggest future work.

2. Problem description

For operations in crossdocks, inbound trucks transport cargos to it, which are immediately sorted out, repackaged, routed and loaded into outbound trucks and then delivered to customers within one day (Alpan et al., 2011a; Boloori Arabani et al., 2011; Boysen, 2010; Konur & Golias, 2013; Miao et al., 2009; Vahdani & Zandieh, 2010). As a result, one of the key issues to implement crossdock as a "JIT" technique in logistics and supply chain management successfully is to develop an efficient truck-dock assignment module in the crossdock management system so that all the cargos can be delivered to customers on time (Acar et al., 2012; Alpan et al., 2011b; Konur & Golias, 2013; Lee et al., 2012; Yu & Egbelu, 2008).

As mentioned before, our proposed truck-dock assignment problem is $\mathcal{NP}$-hard, the artificial intelligence tool, such as genetic algorithm, tabu search, simulated annealing and so on, should be a good approach to obtain good-quality solutions efficiently (Li et al., 2012; Liao et al., 2013; Lin et al., 2011; Miao et al., 2009). In order to develop ATS to solve this problem, we need to formulate it into a mathematical model first. Before introducing the model, we should explain some common assumptions which are usually adopted in related literatures (Alpan et al., 2011a, 2011b; Liao et al., 2013; Miao et al., 2009). For this problem, we do not address secondary constraints which account for the loading/unloading times or other buffers between arrival and departure times, since they can be easily dealt with by extending the truck arrival and departure durations. The important constraint is the time window constraint for both inbound trucks and outbound trucks, i.e. each inbound/outbound truck can occupy an inbound/outbound dock to unload/load only within its pre-allocated arrival time and departure time. Also we take operational time of transferring, sorting and repacking within the crossdock into consideration. For example, if outbound truck A at outbound dock a is going to receive cargos from inbound truck B at inbound dock b, then inbound truck B needs to ship the cargos to dock a before truck A leaves when taking time window and the operational time for cargos between inbound dock b to outbound dock a into consideration, while the operational time is usually decided by the physical distance between the two docks. As we know, the crossdock management system should schedule the trucks well in order to deliver cargos to customers on time. If it is found that some trucks cannot be assigned due to the limited number of docks, those trucks need to be rescheduled to complete their tasks. The trucks can be delayed, or rescheduled to other crossdocks where a vacancy is available. In such situations, a penalty cost is incurred for any unfulfilled cargo shipment. Fig. 1 illustrates an outline of the crossdock and major elements of our problem, where the notations will be introduced in details next.

We formulate our proposed problem into a $0-1$ IP model, for which the following notations are used:

N^I: set of inbound trucks arriving at the crossdock, and $|N^I| = n^I$, where $|\cdot|$ represents the cardinality of a set;