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Differential evolution and Population-based simulated annealing for truck scheduling problem in multiple door cross-docking systems

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ABSTRACT

Scheduling of inbound and outbound trucks, which decides on the succession of truck processing at the receiving and shipping dock, is particularly significant to ensure a rapid turnover and on-time deliveries. In this paper, we adopt Just-In-Time (JIT) philosophy in truck scheduling problem, where the interchangeability of products, ready times for both inbound and outbound trucks and also different transshipment time between receiving and shipping doors are considered. The objective is to minimize total earliness and tardiness for outbound trucks, in such systems. A mixed integer programming model is developed to formulate the problem and is solved optimally in small-sized instances with ILOG CPLEX solver. Also to solve medium to large-sized cases, two meta-heuristics called Differential evolution and Population-based simulated annealing are employed. The meta-heuristics are tuned by the response surface methodology. Finally, the performances of the meta-heuristics are compared with CPLEX solver in small-sizes instances, and also to each other and Pure Random search in medium to large-sized problems. The computational results demonstrates the efficiency of our meta-heuristics.

1. Introduction

Cross-docking is a logistics technique in which products delivered to a warehouse by inbound trucks are sorted out and rearranged based on customer demands and are moved and loaded into outbound trucks for delivery to customers without being held in the warehouse. Shipments commonly spend less than 24 h in a cross-docking terminal, sometimes less than an hour.

In comparison with traditional warehouses, a cross-docking system can reduce the storage and products retrieval costs by integrating the flows of inbound and outbound trucks. Moreover, the employment of cross-docking systems end in advantageous consequences such as the decrease in inventory levels, operational costs, and delivery time or the increase in throughput and the level of customer satisfaction.

Successful implementation of such systems in popular companies as Wal Mart, Goodyear GB Ltd, Toyota, Eastman Kodak Co and Dots, LLC shows that this strategy can considerably decrease distribution costs (Van Belle, Valckenaers, & Cattrysse, 2012).

Scheduling of trucks is a crucial operational management problem in cross-docking systems that determines sequences of inbound and outbound trucks processes in related assigned doors. A good scheduling can improve product flow, reduce unnecessary waiting times and accordingly decrease lead times for shipping products to customers. Recently, the truck scheduling problem in cross-docking has attracted the attention of researchers.

Many researches consider some other problems in cross-docking such as layout design, location, network and vehicle routing problems. For example Jayaraman and Ross (2003) and Ross and Jayaraman (2008) deal with determining which warehouse and cross-docking are opened and its product allocation, to minimize the total cost. Apte and Viswanathan (2000) offer a framework for understanding and designing cross-docking systems and also, discuss the techniques for enhancing the efficiencies of distribution networks and logistics. Bartholdi and Gue (2004) specify the best shape of a cross-docking system and conclude that it depends on the size of the facility and the pattern of product flows within it. Lee, Jung, and Lee (2006) and Mosheiov (1998) study the pickup and delivery problem as a kind of vehicle routing problem. Vis and Roodbergen (2011) consider a dynamic methodology to design the storage area of cross-docking facilities.

This study focuses on operational problems: the door assignment and the truck scheduling problems. Several studies have been done on the door assignment problem such as Tsui and Chang (1990, 1992), Gue (1999), Bartholdi and Gue (2000), Oh, Hwang, Cha, and Lee (2006), Yu, Sharma, and Murty (2008), Bozer and Carlo (2008), Miao, Lim, and Ma (2009), and Acar, Yalcin, and

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Yankov (2012). If the determination of assigning doors is considered in early step, short-term truck scheduling problem can be considered in the subsequent step.

Li, Lim, and Rodrigues (2004) view the cross-docking scheduling problem like a machine scheduling problem and suggest a JIT based model, to minimize the storage time and order picking activity. They apply two Genetic algorithms to solve the proposed model. Alvarez-Pérez, Gonzler-Velarde, and Fowler (2009) extend the work of Li et al. (2004) by developing different meta-heuristic procedures. McWilliams, Stanfield, and Geiger (2005) and McWilliams, Stanfield, and Geiger (2008) study scheduling of inbound trucks at a cross-dock used in the parcel delivery industry. In such cross-docking systems, unloaded parcels are carried to outbound trucks by means a network of conveyors. To deal with the problem, they present a simulation-based scheduling algorithm in order to minimize the total operation time. McWilliams (2009a) and McWilliams (2010) consider such problem, but the objective is balancing the workload. The problem is formulated as a minimax programming model and several meta-heuristic algorithms are proposed to solve the model. McWilliams (2009b) also present a dynamic version of the same problem.

Yu and Egbelu (2008), Vahdani and Zandieh (2010), Vahdani, Soltani, and Zandieh (2010), Soltani and Sadjadi (2010), Forouharfard and Zandieh (2010), Fazel Zarandi, Khorshidian, and Shirazi (2014), Ghobadian, Tavakkoli-Moghaddam, Javanshir, and Naderi-Beni (2012), Ghobadian, Tavakkoli-Moghaddam, Naderi-Beni, and Javanshir (2013), Boloori Arabani, Fatemi Ghomi, and Zandieh (2010) and Boloori Arabani, Fatemi Ghomi, and Zandieh (2011) study a sequencing problem at a specialized cross-docking terminal, in which one receiving dock door serves one shipping dock door. Yu and Egbelu (2008) propose a MIP model to find the best sequence for both inbound and outbound trucks, when a temporary storage buffer to hold items is located at the shipping dock. The model simultaneously determines, the product assignment to trucks and the docking sequences of the both inbound and outbound trucks. Vahdani and Zandieh (2010), Boloori Arabani et al. (2011) suggest solution methods based on meta-heuristic algorithms for the same problem. Boloori Arabani et al. (2010) deal with a cross-docking system with similar assumptions, but they consider a multi-criteria scheduling in which the primary objective is minimizing the total earliness and tardiness simultaneously. Forouharfard and Zandieh (2010) deal with the scheduling of receiving and shipping trucks in cross-docking systems which have a temporary storage in front of shipping dock. They propose an imperialistic competitive algorithm (ICA) approach to minimize the total number of products that pass through temporary storage. The results show that this algorithm outperformed GA. Fazel Zarandi et al. (2014) study the scheduling of trucks for minimizing the total earliness and tardiness in a cross-docking terminal with a single receiving and shipping door. They propose an Integer Programming (IP) model to solve the problem. Due to the NP-hardness of the problem, a genetic algorithm is developed for solving the model. Vahdani et al. (2010) study the truck scheduling problem in a cross-docking terminal in which there is no temporary storage. They propose GA and electromagnetism-like algorithm (EMA) to minimize the total flow time of system in such systems. Ghobadian, Tavakkoli-Moghaddam, Javanshir, and Naderi-Beni (2012) develop greedy randomized adaptive search procedure (GRASP) algorithm to solve a truck scheduling problem in a special case of cross docking where there is temporary storage. Ghobadian, Tavakkoli-Moghaddam, Naderi-Beni, and Javanshir (2013) propose GA for solving the same problem.

Boysen and Fliedner (2010) present a classification of truck scheduling problems based on a tuple notation. They show that the models existing in classification are NP-hard in the high sense. Hence, future research should propose efficient exact and especially heuristic and meta-heuristic procedures for this and similar optimization models. Additionally, they offer a new truck scheduling problem model for fixed outbound schedules. Boysen, Briksorn, and Tschöke (2013) develop decomposition procedures and simulated annealing to solve the model. Also, they present a case study for their research. Alpan, Larbi, and Penz (2011), consider a truck scheduling problem, in which preemption of unloading and loading is allowed. Lee, Kim, and Joo (2012), study the scheduling of inbound and outbound trucks in multi-door cross-docking systems. They propose a mathematical model to maximize the number of products that are able to ship in a given working horizon. They use three genetic algorithms for the proposed model. Liao, Egbelu, and Chang (2013) consider the simultaneous dock assignment and sequencing of inbound trucks for a multi-door cross-docking terminal with the objective of minimizing total weighted tardiness, under a fixed outbound truck departure schedule. Ladier and Alpan (2014) deal with scheduling of inbound and outbound trucks, also planning the internal pallet handling in a cross-docking platform to minimize both total number of pallets put in storage and the dissatisfaction of transportation providers. They show that the problem is NP-hard, so three heuristics are proposed to solve the problem. Konur and Golias (2013) determine scheduling of trucks with unknown arrival times for trucks by offering a bi-objective genetic algorithm. In particular, they assume that only acknowledges the arrival time window of each truck. In this condition, the cross-dock operator can apply three approaches: deterministic approach (expected truck arrival times are equal to their mid-arrival time windows), pessimistic approach (the worst truck arrivals will be realized), and optimistic approach (the best truck arrivals will be realized). They use GA to solve the problem for different conditions. The results conclude that a hybrid approach regarding the optimistic and pessimistic approaches outperform all of the three approaches. Joo and Kim (2013), consider a truck scheduling problem for inbound-only trucks, outbound-only trucks, and compound trucks in a multi-door cross-docking system. They offer a mixed integer programming (MIP) model to minimize the makespan, in such systems. Van Belle, Valckenaers, Vanden Berghe, and Cattrysse (2013) deal with scheduling of inbound and outbound trucks at multiple dock doors. They are proposed a mixed integer programming model to minimize the total tardiness and the total travel time. In order to solve the model, a tabu search algorithm is developed. Madani-Isfahani, Tavakkoli-Moghaddam, and Naderi (2014) consider a truck scheduling problem in a multiple cross-docks. Inbound and outbound trucks can intermittently move in and out of the docks during the time intervals between their task executions, in which trucks can enter to each of the cross-docks. So, they develop a MIP model for multiple cross-docks scheduling, in order to minimize the makespan. Also, to solve the offered model, they propose two meta-heuristics, namely simulated annealing and firefly algorithms.

In order to highlight the contribution of this paper, we present the most related works to our study in Table 1. All of these papers, consider the interchangeability of products and assume that each door is exclusively designated for receiving or shipping. In Table 1 the similarities and differences of our assumptions to other works, and the notation of scheduling models according to Boysen and Fliedner (2010) classification are presented.

The terms in Table 1 columns can be described as follows:

No. of doors: Total number of receiving and shipping doors.
Pre-emption: If pre-emption is allowed, the loading or unloading of a truck can be interrupted.
Ready time (arrival time): Trucks are either already waiting on the yard and, thus, readily available to be called up or arrive after the start of the schedule, so that they may only be