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Truck scheduling in a cross docking systems with fixed due dates and shipment sorting

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ABSTRACT

In this paper, a truck scheduling problem is investigated at a two-touch cross-docking center with due dates for outbound trucks as a hard constraint. The objective is to minimize the total cost comprising penalty and delivery cost of delayed shipments. The sequence of unloading shipments is considered and it is assumed that shipments are sent to shipping dock doors immediately after unloading where a First-In-First-Out (FIFO) policy is considered for loading the shipments. A mixed integer programming model is developed for the proposed model. A hybrid genetic algorithm-reduced variable neighborhood search (HGARVNS) algorithm is developed to solve the problem in medium and large sized scales and compared with common meta-heuristic algorithms used in literature. The numerical results show that the due date can be adjusted between a time-window or postponed to a certain point based on customers' needs or cross-dock limitations. Moreover, we concluded that the sorting of shipments inside inbound trucks can improve the cross-dock performance.

1. Introduction

Cross-docking is a modern strategy used in distribution networks to reduce logistic costs. The benefit of such strategy is significant in today's competitive market and many successful implementations are reported (see for instance Kim, Yang, and Kim (2008), and Boysen, Briskorn, and Tschöke (2013)). The idea of cross-dock is to avoid the costly functions of traditional warehouses such as inventory holding and handling costs. As a result, unloaded shipments are stored usually less than 24 h and are moved to shipping docks through conveyor belts or lift trucks with minimum handling operations (Van Belle, Valckenaers, Berghe, & Cattrysse, 2013).

Many authors have studied truck scheduling problem in a multi receiving-and-shipping dock door cross-dock. Konur and Golias (2013) studied inbound truck scheduling problem with unknown truck arrivals where trucks enter the cross-dock yard in a specific time windows. Van Belle et al. (2013) proposed a truck scheduling problem that each truck has a specific arrival time but this time is known beforehand. Each truck also had a predefined departure time but the constraint is assumed to be soft. Arabani, Ghomi, and Zandieh (2010) studied a similar problem which each truck had a soft departure time and both earliness and tardiness of trucks were due to a penalty cost in a just-in-time approach.

A few researches have studied the problem with predefined departure time for trucks as a hard constraint. Miao, Lim, and Ma (2009) first considered a problem in which trucks arrival time are different and known beforehand and the problem feasibility is related to arrival and departure time windows, cargo transshipment times and cross-dock capacity. Boysen et al. (2013) also considered an inbound truck scheduling problem in which departure time for outbound trucks are fixed. The objective is to minimize the total lost profit which occurs if a shipment is not processed before truck departure. Liao, Egbelu, and Chang (2013) considered the situation in which trucks should leave cross-docking center in a pre-defined departure time. Shakeri, Low, Turner, and Lee (2012) studied a truck scheduling problem that dock doors and internal handling system are constrained resources which may be unavailable through the planning horizon.

Over the recent years many researchers have been attracted to study different aspects of cross-dock systems. Van Belle, Valckenaers, and Cattrysse (2012), Stephan and Boysen (2011) and Buijs, Vis, and Carlo (2014) studied different types of problems in cross-dock systems. Boysen and Fliedner (2010) classified its characteristics into three categories amongst with firstly, door environment including mode of service, number of dock doors, secondly operational characteristics comprising preemption, arrival time, processing time, deadline/due date, intermediate storage, assignment restrictions, transshipment time, outbound organization and interchangeable products, and thirdly, objectives which each category describes different aspects of the operational functions of the cross-dock.

As mentioned above, few papers (Boysen et al., 2013; Miao et al., 2009) have considered the due date for trucks as a hard constraint.

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However, they ignore any continuous variable in order to decrease the complexity of the model. They also transfer the shipments of an inbound truck to the related outbound trucks only if all the shipments are unloaded which has a sensible contrast to the objective which is the minimization of total delayed shipments.

This study tries to surmount the gap in the literature and develop a model which includes real world assumptions. The main contributions of our work can be summarized as follows: First, a hard due date for each outbound truck regardless of the amount of loaded shipments are incorporated which is applicable in cases such as postal services. Second, it is assumed that each shipment can be handled immediately after being unloaded. Third the location of each shipment in the inbound trucks is incorporated into the model; and fourth, a meta-heuristic algorithm which hybridize genetic algorithm and reduced variable neighborhood search is developed. Moreover, the entering time of each truck is different, i.e. each one enters the cross-dock terminal at a specific time not necessarily at the beginning of planning horizon. The organization of the remainder of the paper is as follows: in Section 2 we define the detailed assumptions of the problem and develop a mathematical model. In Section 3, to solve the model and gain near-optimal solutions, a hybrid meta-heuristic algorithm which incorporate genetic algorithm (GA) and reduced variable neighborhood search (RVNS) is developed and compared with differential evolution (DE) and particle swarm optimization (PSO) which are vastly used in the literature. In Section 4, we evaluate the performance of the proposed algorithms through experimental results. Sensitivity analysis and managerial insights are presented in Section 5 and finally, conclusion and further research is disgusted in Section 6.

2. Problem definition

This paper considers a simultaneous inbound and outbound truck scheduling problem with multiple receiving and shipping dock doors in a cross-dock facility. The objective is to minimize the costs related to delayed shipments. Outbound trucks should leave the terminal at predefined times, regardless of the completed loading of shipments. If any shipment does not meet the due date, another truck will be used to deliver it at the end of the planning horizon. One of the real world cases for this problem is the postal service industry in which outbound trucks should move towards the destination at a pre-defined time as discussed by Boysen et al. (2013) where the DHL air-hub in Leipzig is studied. As another example in retailing industry, there are some stores which are not open 24/7. Therefore, their demands should be delivered by the time when the stores are open. Although considering these hard due date constraints can decrease the utility of outbound truck and result in lower productivity of trucks, any tardiness in the delivery of shipments can cause shortage which affects the reputation of retailers. In this model, we consider hard due date to avoid large shortage at retailers and penalize any delayed shipment to increase the productivity of outbound trucks.

In addition, it is assumed that the number of receiving (shipping) doors is equal or smaller than the number of inbound (outbound) trucks. If the number of dock doors is equal or large than that of trucks, the problem is reduced to a dock door assignment. Moreover, it is not necessary to wait until all the shipments are unloaded for start of transshipment process and any shipment is transferred to the shipping dock immediately after unloading. It is worth mentioning that the terms suppliers (customer) and inbound (outbound) trucks are interchangeable. The remaining assumptions are as follows:

- Trucks enter the cross-dock terminal scattered in time. Each truck has a predefined arrival time.
- All demand of an outbound truck from each inbound truck is packed and called a shipment, i.e. several products are packed in a shipment.
- The predefined unloading/loading time depends on inbound truck which provides the shipment as well as the outbound truck which should load that shipment. Moreover, this time depends on the location of the shipment in the inbound truck. For instance, to unload the shipment in the 4th position, the unloading time of 1st to 3rd positions should be taken into account.
- Shipments transferred to shipping dock doors are loaded into outbound trucks only if they meet the due date considering the time of loading the shipment sequence waiting to be loaded.
- Based on the amount of delayed shipments, different types of trucks can be employed at the end of horizon time.
- Transportation time between dock doors depends on the distance between the doors to which the trucks are assigned.
- Service mode of doors is exclusive, and thus inbound and outbound trucks are processed only at receiving and shipping doors, respectively.
- Temporary storage in the cross-docking center is allowed.
- Capacity of the resources inside the cross-dock are considered unlimited.
- Pre-emption is not allowed neither in inbound nor in outbound trucks.
- Shipments are not interchangeable. Pre-distribution assignment is considered.

Indices

I	Set of inbound trucks ($i,i' \in I$)
K	Set of outbound trucks ($k,k' \in K$)
J	Set of receiving dock doors ($j,j' \in J$)
L	Set of shipping dock doors ($l,l' \in L$)
H	Set of vehicle types for delivery of delayed shipments at the end of planning horizon ($h \in H$)

Parameters

a_i	Arrival time of inbound truck i
b_k	Arrival time of outbound truck k
d_k	Due date of outbound truck k
m_{hk}	Cost of vehicle type h to deliver delayed shipments of outbound truck k at the end of planning horizon
Cap_h	Capacity of vehicle type h
f_{ik}	The number of products in a shipment that should be loaded to outbound truck k provided by inbound truck i
θ_{ik}	The position of shipment needed by outbound truck k in inbound truck i, i.e. it determines the sequence of unloading of shipments which were initially loaded into inbound truck i
w_{ik}	The importance weight of each shipment from inbound truck i to outbound truck k
ρ_{ik}	The time needed to put a product of a shipment from inbound truck i to outbound truck k onto conveyor belts
t_{jl}	Travel time between receiving dock j and shipping dock door l
T_{ik}	The time needed to unload/load a product in a shipment provided by inbound truck i and should be delivered to outbound truck k
TC	Truck changeover time
M	A big positive number

Positive variables

α_i	Assignment time of inbound truck i to receiving dock door
β_k	Assignment time of outbound truck k to shipping dock door
D_i	Completion time of inbound truck i
c_k	Completion time of outbound truck k
λ_{ik}	The start time of sending unloaded shipment from inbound truck i to outbound truck k
μ_{ik}	

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