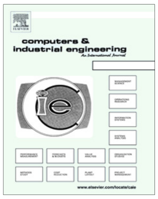
Computers & Industrial Engineering 72 (2014) 43–49

Contents lists available at ScienceDirect

Computers & Industrial Engineering

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



A sequential priority-based heuristic for scheduling material handling in a satellite cross-dock ☆

M.Y. Maknoon [a,*], O. Kone [b], P. Baptiste [a]

[a] Department of Mathematics and Industrial Engineering, Polytechnique Montréal, Montréal, Québec H3C 3A7, Canada
[b] Mathematics and Computer Laboratory, Nangui Abrogoua University, Abidjan, Ivory Coast

ARTICLE INFO

Article history:
Received 20 May 2013
Received in revised form 5 December 2013
Accepted 3 March 2014
Available online 15 March 2014

Keywords:
Less-than-truckload
Satellite cross-dock
Material handling
Mixed-integer programming
Heuristics

ABSTRACT

In a less-than-truckload logistic network, the satellite cross-dock is in charge of local deliveries. These terminals operate in two separate shifts: consolidating pickup freight for overnight shipments and processing received products for early morning deliveries. Satellite cross-docks are flexible when scheduling trucks and where the priority is to minimize handling cost. In this paper, we formalize cross-docking process by presenting a mathematical model. We develop a sequential priority-based heuristic algorithm to deal with practical problems. Numerical results show the stability of the heuristic method for fairly large size problems.

1. Introduction

Cross-dock is a transhipment center with the function of consolidating arriving freight with the same destination in order to have full outgoing truckloads. Cross-docking is widely practiced in Less-than-Truckload (LTL) shipping to improve the economy of scale in transportation (Apte & Viswanathan, 2000). Furthermore, it reduces the total inventory level and finds savings in storage costs. However, cross-docking is beneficial as long as its handling costs do not overwhelm the savings in transportation and inventory costs (Bartholdi & Gue, 2004).

Generally, the LTL network employs a hub-and-spoke arrangement to shift freight. In this strategy, a satellite terminal is responsible for local deliveries. The special working structure of these cross-docks provides flexibility with the network timing schedule. Satellite cross-docks operate in two separate working shifts. In the first shift, the terminal groups inbound freight for scheduled early morning deliveries, whereas the picked-up products are consolidated for overnight shipment in the second shift. Outside of these two working periods, the terminal is inactive (Bartholdi & Gue, 2000; Gue, 1999). As a result, the main scheduling concern is to boost the performance of cross-docking by examining the process of material handling.

Research on operational processes of cross-docks can be classified into two categories based on their internal transhipment system: automated and manual.

Some platforms are equipped with highly automated conveyors and sortation systems (e.g., distribution centers in courier industries). Studies for this type of cross-dock deploy a time related objective (e.g., total operational time, tardiness of outbound truck, etc.) to synchronize truck loading and unloading. For a cross-dock with a single receiving and shipping door, Yu and Egbelu (2008) and Boysen, Fliedner, and Scholl (2010) have represented a heuristic method to schedule the order of processing trucks at the terminal to minimize total operational time. This problem has been studied in Vahdani and Zandieh (2010), Soltani and Sadjadi (2010), Boloori Arabani, Fatemi Ghomi, and Zandieh (2011), Larbi, Alpan, Baptiste, and Penz (2011), in which several meta-heuristics have been developed and compared for both deterministic and stochastic scheduling scenarios. McWilliams, Stanfield, and Geiger (2005, 2008) have studied the assignment of trucks to cross-dock doors operating in parcel industries. A genetic algorithm coupled with a simulation model has been applied to minimize total product traveling time within doors.

In contrast, LTL cross-docks use a manual handling system (e.g. forklifts, pallet jack) for internal transhipment. This handling approach is labor intensive and costly (Bartholdi & Gue, 2000). In fact, a major share of operational costs in LTL cross-docks is associated

---

☆ This manuscript was processed by Area Editor Manoj Tiwari.

* Corresponding author. Tel.: +1 5147314906.

E-mail addresses: mohammad-yousef.maknoon@polymtl.ca (M.Y. Maknoon), mr.okone@gmail.com (O. Kone), P.Baptiste@poltml.ca (P. Baptiste).

http://dx.doi.org/10.1016/j.cie.2014.03.002
0360-8352/© 2014 Elsevier Ltd. All rights reserved.

with material handling (Gue, 1999), which is influenced by the manner in which the manipulation of products is performed inside the terminal.

In early studies on cross-docks with two doors, the problem was formulated and solved by implementing a heuristic method (Maknoon & Baptiste, 2009), which is an NP-Hard problem (Sadykov, 2012). Although these studies provide insight into the structure of a solution, in reality, platforms with multiple doors need to be dealt with.

For a terminal with multiple doors, Alpan, Larbi, and Penz (2011b) have studied a truck sequencing problem to minimize cross-docking expenses. Here, the operational cost has been expressed as storage and truck replacement costs (truck replacement is a process of temporarily moving semi-unloaded trucks into a parking area in order to liberate terminal door). They have also considered a First-In-First-Out (FIFO) transhipment policy. This policy enforces time restrictions on storing products inside the terminal. Dynamic programming has been suggested and several heuristics have been proposed to enhance the solution quality (Alpan, Ladier, Larbi, & Penz, 2011a).

In this paper, we focus on scheduling transhipment processes at a satellite cross-dock. In these terminals, the main priority is to reduce transhipment costs, which is possible by investigating more in-depth material handling plans. We consider a real platform with multiple doors. However, as a result of the short processing time, these terminals follow special handling rules. First, the truck replacement is forbidden by cross-dock operational regulations, as it is a costly procedure that may interrupt the guaranteed service (Bartholdi & Gue, 2000). Second, FIFO transhipment assumption is not valid in our research. By relaxing this restriction, we will be able to gain further savings in handling costs.

The remainder of this paper is organized as follows: in Section 2, we describe the cross-docking operation and present a mathematical model to optimize the material handling plan. The methodology for the solution is discussed in Section 3. Computational results are reported in Section 4 followed by a conclusion in Section 5.

2. Problem definition and modeling approach

In this section, we begin by describing cross-docking in a satellite terminal. Then, we represent our modeling approach with the help of an illustrative example. Finally, we formalize decisions on material handling by introducing a mathematical formulation of the problem.

2.1. Cross-docking operations and model representation

Cross-docks are generally rectangular-shaped terminals with multiple doors. Each door exclusively processes inbound or outbound trucks. The terminal uses various layouts depending on their internal process. Here, we study the one with a small staging area in front of each door and an internal storage in the center of the terminal. Fig. 1 represents a schematic layout of the cross-dock studied.

Before describing a cross-docking operation, let us discuss the distribution environment and the way products are recognized in our scheduling model. The LTL cross-dock operates in a pre-distribution environment; that is, the shipper is responsible for product preparation, including packaging and labelling, with respect to its final delivery destination. Therefore, the consolidation process at the terminal is to unify products based on their assigned destination. With this description, for scheduling purposes, we recognize products by their final destination. As a result, incoming trucks contain products for various destinations, whereas the outgoing trucks carry products to a single destination.

Table 1
Content of incoming trucks.

Destination/truck	i	ii	iii	iv	v	vi	vii	viii
A	20	25	23	25	17	30	24	26
B	21	27	24	26	25	20	28	29
C	31	22	22	22	30	23	21	27
D	28	26	31	27	28	25	17	18

The cross-docking process can be classified into three main interrelated operations: (1) processing trucks, (2) transferring products and (3) consolidating shipments. Truck processing refers to the period of time during which a truck loads or unloads at the terminal. In this paper, we specify this period according to two sequences representing the assigning and releasing order of the truck. As mentioned earlier, the assigning order of incoming trucks follows the First-Come-First-Served rule (FCFS), while the rest of the orders are determined based on the cross-dock plan. For an unloaded product, two transferring decisions exist: either moving it to the outbound door or transferring it to temporary storage for future reshipment. Finally, the consolidation decision is to load outgoing trucks by combining products at receiving doors with the ones at terminal storage.

Inside the cross-dock, manual handling devices such as forklifts or pallet jacks are used for product manipulation. Considering an opportunity cost for operators and transporters, double-handling (transferring products to the storage area) is an inefficient transhipment decision that spends terminal resources. In addition, there is a supplementary cost of storage and retrieval for temporary stored products inside the cross-dock. Therefore, our scheduling model seeks to synchronize truck processing, internal transhipment and the consolidation process to minimize the cost of material handling.

Suppose I and J are the sequences representing processing period of trucks at the terminal. Each sequence has an ordered n-tuple $(\mathcal{A}|\mathcal{R})$, in which "$\mathcal{A}$" and "$\mathcal{R}$" are the assigned and released truck, respectively. The cross-docking operation can be shown on a graph G with $|I| \times |J|$ states. As shown in Fig. 2, state $(\Omega_{(i,j)})$ is the period of time in which a set of incoming and outgoing trucks are presented at the terminal. From each state $(\Omega_{(i,j)})$, there are at most two transition possibilities: either $\Omega_{(i+1,j)}$ by replacing a truck at the receiving doors or $\Omega_{(i,j+1)}$ by changing a truck at the shipping doors.

Based on the aforementioned definition, the first state $(\Omega_{(0,0)})$ represents the time when the first incoming and outgoing trucks are assigned to the terminal door. In a similar fashion, the last state $(\Omega_{(|I|,|J|)})$ is a time period when the last incoming and the last outgoing trucks are processed at the terminal. The path that connects the first state to the last one is called an "operational plan". The operational plan provides decisions on product transhipment and consolidation at each state. However, even when the processing time

Table 2
Data characteristics.

Platform setting			Distribution of incoming trucks (DIT)		
#Truck	#Doors	#Dest.	#1	#2	#3
16	4	4	$d_{1:4}^{25\%}$	$d_{1}^{37.5\%}, d_{2:3}^{25\%}, d_{4}^{12.5\%}$	$d_{1:2}^{37.5\%}, d_{3:4}^{12.5\%}$
		6	$d_{1:2}^{25\%}, d_{3:6}^{12.5\%}$	$d_{1}^{37.5\%}, d_{2:6}^{12.5\%}$	
		8	$d_{1:8}^{12.5\%}$		
120	10	10	$d_{1:10}^{10\%}$	$d_{1:5}^{13\%}, d_{6:10}^{6\%}$	$d_{1:5}^{15\%}, d_{6:10}^{5\%}$
		15	$d_{1:15}^{6.6\%}$	$d_{1:10}^{5\%}, d_{11:15}^{10\%}$	$d_{1:2}^{15\%}, d_{3}^{10\%}, d_{4:15}^{5\%}$
		20	$d_{1:20}^{5\%}$	$d_{1:10}^{6\%}, d_{11:20}^{3.3\%}$	$d_{1:5}^{10\%}, d_{6:20}^{3.3\%}$