Transportation Research Part E 49 (2013) 71–91

Contents lists available at SciVerse ScienceDirect

Transportation Research Part E

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

Cost-stable truck scheduling at a cross-dock facility with unknown truck arrivals: A meta-heuristic approach

Dinçer Konur [a,b,*], Mihalis M. Golias [b,c]

[a] Missouri University of Science and Technology, Engineering Management and Systems Engineering, 600 W. 14th St., Rolla, MO 65409, United States
[b] Center for Intermodal Freight Transportation Studies, University of Memphis, 302 Eng. Admn. Bldg., Memphis, TN 38152, United States
[c] Civil Engineering Department, University of Memphis, Eng. Sci. Bldg., Memphis, TN 38152, United States

A R T I C L E I N F O

Article history:
Received 20 February 2012
Received in revised form 8 June 2012
Accepted 17 June 2012

Keywords:
Cross-dock operations
Unknown truck arrivals
Stable scheduling
Bi-objective optimization

A B S T R A C T

We study a cross-dock operator's truck scheduling problem at inbound doors in case of unknown truck arrival times. Due to uncertainty of truck arrivals, a scheduling strategy is subject to variations in costs of serving the trucks. A cost-stable scheduling strategy is defined as a schedule with low variation levels. In this paper, we analyze the cross-dock operator's problem of determining a cost-stable scheduling strategy while minimizing the average of total service costs. A bi-objective bi-level optimization problem is formulated and we discuss a genetic algorithm based heuristic to find Pareto efficient schedules. The proposed approach is compared to first-come-first-served policies.

1. Introduction and literature review

It is well known that cross-docking may achieve substantial savings for a supply chain (see, e.g., Kinnear, 1997; Gümüş and Bookbinder, 2004; Waller et al., 2006; Kreng and Chen, 2008; Galbreth et al., 2008), hence, it is practiced by many companies. The benefits of cross-docking are due to decreased warehousing costs, utilized transportation capacity as consolidated shipments result in fewer but full truckload deliveries, which decreases transportation costs, and increased service levels. The common processes included within a cross-dock facility are unloading incoming trucks at the inbound doors, sorting, storing and staging, and loading outgoing trucks at the outbound doors.[1]

A successful cross-docking implementation requires efficiently locating cross-dock facilities within supply chain networks (see, e.g., Syarif et al., 2002; Jayaraman and Ross, 2003; Sung and Song, 2003; Gümüş and Bookbinder, 2004; Campbell, 2005; Chen et al., 2006; Ross and Jayaraman, 2008; Bachlaus et al., 2008; Sung and Yang, 2008; Kreng and Chen, 2008), designing the layout of the cross-dock facilities (see, e.g., Bartholdi and Gue, 2004; Heragu et al., 2005; Hauser and Chung, 2006; Vis and Roodbergen, 2008; Yanchang and Min, 2009), and planning cross-dock operations. The studies on cross-dock operations constitute the major part of the literature on cross-docking. In a recent study, Agustina et al. (2010) review the studies on cross-dock operations. It is noted that allocating products to cross-dock facilities (Li et al., 2008, 2009), assignment of docks based on delivery origins and destinations (Tsui and Chang, 1990, 1992; Gue, 1999; Bartholdi and Gue, 2000; Bermudez and Cole, 2001; Oh et al., 2006; Lim et al., 2006; Bozer and Carlo, 2008; Ko et al., 2008; Miao et al., 2009; Marjani et al., 2011; Shuib et al., 2012), vehicle routing in networks with cross-docks (Lee et al., 2006; Wen et al., 2009), transfer of

* Corresponding author at: Missouri University of Science and Technology, Engineering Management and Systems Engineering, 600 W. 14th St., Rolla, MO 65409, United States. Tel.: +1 352 870 5269.
E-mail address: dkonur@memphis.edu (D. Konur).
URL: http://plaza.ufl.edu/dincer/ (D. Konur).

[1] Storage times at cross-dock facilities are generally less than a day (see, e.g., Yu and Egbelu, 2008; Alpan et al., 2011).

1366-5545/$ - see front matter
http://dx.doi.org/10.1016/j.tre.2012.06.007

loads from inbound doors to outbound doors (Lim et al., 2005; Miao et al., 2008), and scheduling incoming and outgoing trucks at inbound and outbound doors (cross-dock scheduling), respectively, are the main challenges observed in cross-dock facilities. Most of the studies on cross-dock operations focus on cross-dock scheduling.

In a cross-dock scheduling problem, the goal is to determine the assignment of incoming (outgoing) trucks to inbound (outbound) doors and each truck's order of service. It is worth noting that the cross-dock scheduling problem is different than the dock-door assignment problem, which seeks the optimal assignment of incoming and outgoing trucks to the dock doors of a cross-dock facility (Belle et al., 2012). In particular, the cross-dock scheduling problem takes time dimension into account while time is not considered in the dock door assignment problem (Belle et al., 2012). As noted by Boysen and Fliedner (2010), door environment (dock assignments, number of doors, and inbound-only, outbound-only, and mixed doors) and operational characteristics such as truck arrivals, preemptions, shipment deadlines, and storage restrictions affect truck scheduling at cross-dock facilities. Furthermore, it is noted that the objectives are mainly time related such as minimization of makespan, total service times, and tardiness. In the cross-dock scheduling literature, such objectives are studied assuming that either all trucks are present at the cross-dock facility at the beginning of a planning period or the time each truck arrives at the cross-dock facility is known in advance. McWilliams et al. (2005), Shakeri et al. (2008), Yu and Egbelu (2008), Maknoon and Baptiste (2009), and Boysen et al. (2010) assume that truck arrival times are identical and equal to zero, i.e., all trucks are available at the beginning of the planning period. Sadykov (2009), Vahdani and Zandieh (2010), and Alpan et al. (2011), on the other hand, assume that truck arrival times are given. However, assuming known truck arrival times with certainty is unrealistic as truck arrivals are subject to uncertainties due to traffic congestion, weather conditions, or engine failures (Boysen and Fliedner, 2010). This assumption, therefore, may result in suboptimal scheduling strategies in practice (Boysen, 2010) and affect cross-docking efficiency as waiting and delivery times heavily depend on the scheduling strategies (Wang and Regan, 2008). In a recent review of cross-docking studies, Belle et al. (2012) note that assuming deterministic travel times and costs is a shortcoming of the truck scheduling studies in the literature. The current paper is intended to overcome this by considering uncertainty of truck arrivals in inbound truck scheduling at a cross-dock facility. One may refer to Boysen and Fliedner (2010) and Agustina et al. (2010) for a review of cross-dock scheduling problems and a review on mathematical models considered in cross-dock operations, respectively. Belle et al. (2012) provide a detailed literature review on different aspects of cross-docking.

In this study, truck arrival times are assumed to be unknown in an attempt to better represent the realistic properties of cross-dock operations by accounting for the uncertainties in truck arrivals. As noted by Stock and Lambert (2001), inbound transportation is subject to higher levels of uncertainty; therefore, the focus of the current study is on incoming truck scheduling at the inbound doors at a cross-dock facility under truck arrival times uncertainty. It is observed that there is a limited number of studies that consider uncertainties in cross-docking operations. Rodriguez-Velasquez et al. (2010) and Arnaout et al. (2010) use simulation to model transportation between a set of warehouses and a set of cross-dock facilities to account for stochastic order sizes generated at the warehouses. Larbi et al. (2011) consider stochastic loads of incoming trucks and they study three cases: full-information, partial-information, and no-information on the incoming trucks' loads. They focus on a single inbound and a single outbound door case and the emphasis is on assigning the incoming loads to outgoing trucks.

In this paper, it is assumed that truck arrival times are unknown to the cross-dock operator, however, s/he knows the incoming trucks' arrival time windows, i.e., the lower and upper bounds on the truck arrival times. We consider that the cross-dock operator plans his/her scheduling strategies based on the total service costs. Similar to Alpan et al. (2011), we directly focus on operational costs of scheduling. In particular, each incoming truck has a process (handling) cost depending on the inbound door it is assigned to. Boysen et al. (2010) note that this better reflects practical operations at the cross-dock facilities. Furthermore, the cross-dock operator is subject to waiting costs of the incoming trucks. Specifically, truck waiting times are subject to penalties considering the Just-in-Time scheduling (see, e.g., Alvarez-Perez et al., 2009). Arabani et al. (2010) point out that delays in shipments can result in shortage costs at the destinations. One can consider truck waiting as inventory holding, hence, it results in inventory holding costs as well. In addition, truck waiting times are associated with driver labor cost during the wait. Therefore, we consider that the cross-dock operator has costs associated with truck waiting times. Particularly, we consider that each incoming truck has a specific waiting cost per unit time.

In the case of truck arrival uncertainties, a simple approach is to use a first-come-first-served (FCFS) policy. However, FCFS policies do not result in a stable schedule, that is, the schedule is not known until the last incoming truck arrives at the cross-dock facility and it changes for different truck arrival time realizations. Therefore, trucks' waiting and process costs are both subject to variations. A fixed schedule is desirable by a cross-dock operator for planning purposes such as workforce planning, service pricing, and material handling equipment capacity planning. Variations in schedule costs hinders the efficiency of such planning decisions. While a fixed schedule would not have variations in process costs, there will still be variations in total service costs due to the fact that trucks' waiting costs vary as a result of truck arrival uncertainty. However, these variations are expected to be lower compared to a FCFS policy, under which variations can be observed in trucks' waiting and process costs. Cook et al. (2005) note that stable scheduling is important for lean cross-dock facilities. A stable schedule is also important for outbound transportation as variations in inbound scheduling transfer to variations in outbound scheduling, which increases costs due to delays, increased storage, or additional staging effort. Therefore, we take into account the variations in total service costs associated with a schedule in solving the cross-dock operator's scheduling problem.

In particular, a bi-objective optimization problem is formulated where the first objective minimizes the average total service costs and the second objective minimizes the cost range. Total costs associated with a schedule heavily depend on the