Computers & Industrial Engineering 63 (2012) 729–738

Contents lists available at SciVerse ScienceDirect

Computers & Industrial Engineering

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

Robust door assignment in less-than-truckload terminals ☆

Korhan Acar [a,1], Ali Yalcin [b,*], Daniel Yankov [c,2]

[a] A.T. Kearney, 222 West Adams, Chicago, IL, 60606, United States
[b] University of South Florida, Industrial and Management Systems Engineering Department, 4202 East Fowler Ave. ENB 118, Tampa, FL 33620, United States
[c] Varna International Airport, Fraport Twin Star Airport Management AD, Varna, Bulgaria

ARTICLE INFO

Article history:
Received 28 January 2011
Received in revised form 4 November 2011
Accepted 17 April 2012
Available online 7 May 2012

Keywords:
Transportation
Less-than-truckload
Cross docking
Uncertainty
Door assignment

ABSTRACT

The assignment of incoming trailers to strip doors is one of the critical decisions that affect the performance of cross docking operations in less-than-truckload terminals. This paper introduces a mixed integer quadratic model with the objective of generating trailer-to-door assignments that equally distribute idle times at doors to accommodate operational level uncertainty encountered in truck arrival times. A door assignment heuristic is presented. The performance of the heuristic is compared with optimal solutions to small problems. The effectiveness of the proposed heuristic is studied under a variety of circumstances and terminal sizes. The simulation results show that the proposed heuristic is applicable to realistic-size terminals, and it is effective when variability in truck arrival and service times is considered.

1. Introduction

In less-than-truckload (LTL) freight transportation, for every origin–destination pair of traffic demand, the corresponding freight is shipped either directly or indirectly through intermediate nodes where the traffic is consolidated and re-routed. Most models for freight routing are defined over a network whose nodes represent origins, destinations and intermediate transfer points, and the arcs of the network represent channels of transport e.g. highways. One then distinguishes between local problems involving only a node (terminal) or an arc of the network, and global problems involving multiple entities.

The travel time of freight from its origin to its destination consists of the time spent between the nodes and time spent at the nodes. Since the distances between the nodes are fixed, substantial decrease in these times is less likely than a decrease in the time spent in the terminals and, in some cases, the variance and the duration of time spent at the nodes is considerably higher than the time spent transferring freight between nodes.

In an LTL terminal, freight from arriving trailers flows through the terminal to departing trailers in a cross docking environment without accumulating significant inventories. Freight is unloaded from trucks and reloaded onto another vehicle by means of individual transportation units such as forklifts. The number of doors in an LTL terminal typically ranges from 10 to 200 or more. The two types of doors in LTL terminals are strip doors for receiving (unloading), and stack doors for shipping (loading) to destinations as depicted in Fig. 1. The assignment of arriving and departing trailers to a door, *the door assignment problem* (DAP), is one of the critical decision factors that affect the performance of LTL terminals.

2. Literature review and motivation

A recent survey by Agustina, Lee, and Piplani (2010) presents a comprehensive review of mathematical models for cross dock planning. The review compiles and categorizes over 50 articles according to operational, tactical and strategic planning decisions considered in the referenced work. The door assignment problem considered in this paper falls under the category of operational level decision making problems along with the truck scheduling problem.

The truck scheduling problem which determines the succession of inbound and outbound trucks is probably the most well studied operational level cross docking problem. A recent survey by Boysen and Fliedner (2010) focuses on the truck scheduling models and follows a structured classification scheme based on three parameters, namely door (processor) environment, operational characteristics and an objective to be followed to organize the literature in this topic. More recent notable work in this area includes the work of Boloori Arabani, Fatemi Ghomi, and Zandieh (2010, 2011b),

☆ This manuscript was processed by Area Editor Alexandre Dolgui.
* Corresponding author. Tel.: +1 813 974 5590; fax: +1 813 974 5953.
E-mail addresses: korhan.acar@atkearney.com (K. Acar), ayalcin@usf.edu (A. Yalcin), daniel.yankov@fraport-bulgaria.com (D. Yankov).
[1] Tel.: +1 858 583 1862; fax: +1 312 223 6200.
[2] Tel.: +359 82 884 733; fax: +359 82 884 395.

0360-8352/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.cie.2012.04.008

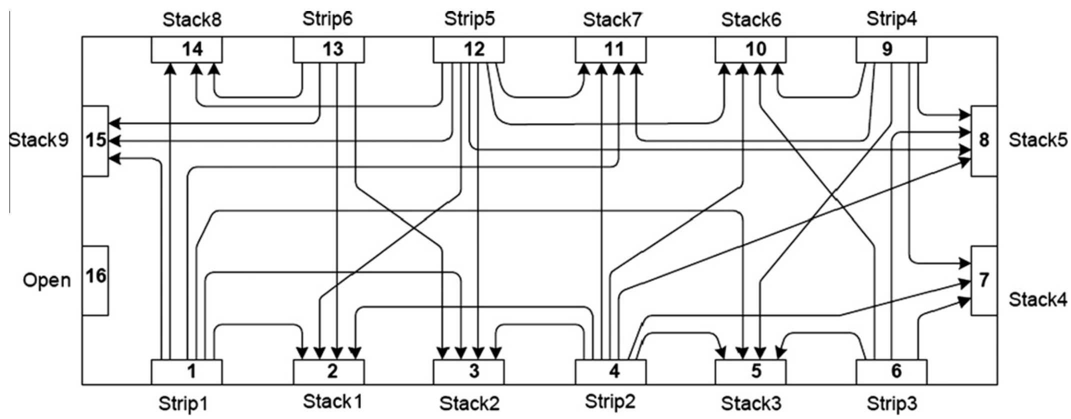

Fig. 1. Freight flow in an LTL terminal (Bermudez & Cole, 2000).

Boloori Arabani, Zandieh, and Fatemi Ghomi (2011a) and Vahdani and Zandieh (2010) which compare the solutions of various heuristics to the truck scheduling problem originally defined in Yu and Egbelu (2008).

Regarding the door assignment problem in LTL terminals, the earliest work is found in Peck (1983) where a greedy balance algorithm is presented to improve terminal productivity by assigning arriving trailers and departing trailers to doors to minimize total distance material handlers travel during transfer operations. Tsui and Chang (1992) formulated the door assignment problem with the objective of minimizing the total distance traveled to move items. The formulation is a static distance minimization formulation and it is reported that changing shipping patterns only occasionally warrants re-adjustment of door assignments. Bermudez and Cole (2000) solve a similar problem with the objective of minimizing total weighted distance using genetic algorithms.

Bartholdi and Gue (2000) suggest that a DAP model with the objective function of minimizing distance does not necessarily improve the performance of the terminal since it can lead to internal congestion. A model of travel cost inside the terminal is described along with two types of congestion. Using these models, alternative layouts are constructed. They report 11% improvement in productivity in a terminal. Gue (1999a) develops a look-ahead door assignment model and reports that the model cuts the labor costs by 15% compared to FCFS policy generally used by terminal supervisors.

Brown (2003) investigates the assignment of trailers to doors and the sequencing approach for unloading freight. Using a semi-permanent and dynamic door assignment approach, improvements in travel distance and labor time are reported over the permanent door assignment approach frequently used in the industry.

Bozer and Carlo (2008) formulate the door assignment problem as a mixed integer programming model with the objective of minimizing material handling. Simulated Annealing is used to solve the model taking into consideration congestion and robustness. Real-life data from a national carrier is used to demonstrate the efficacy of the proposed solution approach.

Operational performance of parcel distribution centers (while different from LTL terminals in that the parcels are transferred via an automated conveyor network) is also significantly impacted by the decisions concerning door assignments. Masel and Goldsmith (1997) investigate the assignment of destinations to load doors focusing on flow congestion in the terminals and balancing workloads at load doors based on historical parcel demand mix. McWilliams, Stanfield, and Geiger (2005) consider the scheduling of arriving trailers in a parcel distribution center using a simulation-based scheduling algorithm integrating Monte Carlo simulation model with genetic algorithms. They report significant improvements in operational performance over current practices in the industry. McWilliams, Stanfield, and Geiger (2008) extends the simulation-based scheduling approach with a list-schedule procedure. McWilliams (2009) models the scheduling of the incoming trailers as a minimax problem and uses a genetic algorithm to search for good solutions. Most recently McWilliams (2010) presents iterative improvement algorithms which are reported to offer superior solutions than genetic algorithms.

In an LTL terminal, operational level activities are impacted by several sources of uncertainty. These are:

1. *Truck arrival times*: Arrival times of trucks do not follow a precise schedule. Traffic congestion and other contingencies prevent precise planning. In the LTL industry, the assignment of arriving trucks to strip doors is made after the truck arrives at its destination.
2. *Truck departure times*: Departure times also exhibit considerable variability. For example, some trucks departing for end-of-line terminals (terminals used for pick-up and delivery of freight) must closely follow a time schedule to make sure that the freight at the destination terminal is available to be carried back to the hub. On the other hand, trucks that operate between break-bulk terminals (intermediate sorting points for interregional freight) have a time window for departure.
3. *Freight flow*: In the LTL industry, the variability of the type of freight is high, and there are peak times during the day, the month and the year where the demand varies on the order of 10–20% (Acar, 2004).

In practice, supervisors try to assign incoming trailers to doors close to the destination trailers for which they have the most freight. Such assignments are generally constructed based on intuition and experience. This becomes difficult as the terminal gets larger. Ultimately, the supervisor's goal is to make assignments that minimize handling of freight and this almost always involves minimizing worker travel (Gue, 1999a).

This paper addresses the unique issues related to the operational level uncertainties in LTL transportation and introduces a robust door assignment methodology. Door assignments which do not consider operational level uncertainties may be interrupted by these unexpected events and delay the subsequent activities assigned to that door or require the reassignment of trailers to other doors disrupting the schedules in the entire terminal.

The rest of the paper is organized as follows: Section 3 describes the mixed integer quadratic formulation for the DAP. Section 4 introduces a heuristic to solve the DAP and compares its perfor-