Scheduling of Inbound Trucks at a Cross-Docking Facility: Bi-Objective vs Bi-Level Modeling Approaches

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ABSTRACT
This paper examines the problem of scheduling of inbound trucks to the inbound doors at a cross-docking facility. The authors optimize for two conflicting objectives: minimize the total service time for all the inbound trucks and minimize the delayed completion of service for a subset of the inbound trucks, which are considered as preferential customers. The problem is formulated as a bi-objective and as a bi-level mixed integer problem. Due to the nature of the former and the complexity of the latter formulation, a genetic algorithm and a k-th best based algorithm are proposed as the solution approaches. Computational examples are used to discuss the advantages and drawbacks of each formulation.

Keywords: Assignment Problem, Bi-Level Optimization, Cross-Docking, Heuristics, Hierarchical Programming, Multiple Objectives Programming, Supply Chain Management, Transportation, Warehousing

INTRODUCTION
In today’s customer driven economy, moving products efficiently and cost effectively offers an advantage to companies. An increasing number of companies are finding that cross-docking operations can play an integral part in their distribution model, partially replacing or complementing existing warehousing operations, in achieving these goals. In a typical logistics distribution network, products are sent to a warehousing facility for storing, retrieving, sorting and reconsolidating. Products are subsequently sent out to retailers upon request. However, as inventory costs represent one of the main costs in a supply chain, cross-dock operations become an attractive alternative to warehousing. Cross-docking is a materials handling operation, where products move quickly, and directly from inbound trucks (ITs)
to outbound trucks (OTs), after being resorted or consolidated with limited storage time, normally not exceeding 24 hours. This type of facility is generally used in a “hub-and-spoke” arrangement, where (de)consolidation of cargo occurs, as in the case of transshipment, with products delivered to customers in truckloads (TL). Cross-dock operations, first pioneered by the Wal-Mart Corporation which delivers about 85% of its commodities through cross-dock facilities, – are increasingly adopted by companies. A survey of 547 industry professionals, carried out by Saddle Creek’s, showed that 52% of the respondents used cross-docks and 13% plan to do so within the next one to two years (Saxena, 2007; Laumar, 2008).

Problems relating to cross-dock facilities can be categorized into two large groups: a) problems that consider the facility as a node within a larger transportation network, and b) problems that focus on the operations of the facility. The former problems (Sung & Song, 2003; Lee, Jung, & Lee, 2006; Wen, Larsen, Clausen, Cordeau, & Laporte, 2009) include: a) the routing of vehicles from/to the cross-dock facility, b) the location and the demand allocation to the cross-dock facility, and c) the design of the supply chain network given the cross-dock facilities. The latter problems (Sung & Song, 2003; Bozer & Carlo, 2008) include: a) optimization of operations at the inbound doors (IDs), b) optimization of operations at the outbound doors (ODs), c) optimization of operations within the storage area of the cross-dock facility. ID operations consist of the assignment of an IT to a door and a time slot; unloading and transferring commodities (usually in the form of pallets) from the ITs to the facility; recording of data on incoming products; and assignment of temporary storage location (if needed). OD operations consist of the assignment of OTs to a door and a time slot; transferring commodities and loading them to the OTs; generation of manifests; and recording of information on shipment and vehicle. Operations within the temporary storage area consist of the allocation of temporary storage space to the incoming commodities; deconsolidation; planning of packing and consolidation; etc. Commodities arriving at the cross-dock facility may be loaded directly onto OTs (one-touch complexity); staged on the dock and then loaded onto OTs (two-touch complexity); or staged on the dock, reconfigured and then loaded onto OTs (multiple-touch complexity). Depending on the complexity of the cross-dock facility (one-touch, two-touch, multi-touch), optimizing the different operations can become a rather complex process. One of the most important functions in a cross-dock environment is the determination of the docks and the assignment of time slots to the ITs and OTs.

In this paper we deal with the problem of scheduling of ITs to the available IDs at a cross-docking facility, and we optimize for two conflicting objectives: a) minimization of the total service time for all the ITs, and b) minimization of delay in service completion for a subset of the ITs. The subset consists of ITs that are treated preferentially and which request a certain completion time (preferential ITs). These two objectives are non-commensurable and gaining an improvement on the first objective usually causes degrading performance on the second and vice versa. In this paper we investigate the applicability and efficiency of two game theoretic based formulations that have been used to model conflicting objectives. The first one formulates the problem as a single level bi-objective problem where the Pareto-optimal front is obtained for the two objectives. The second one formulates the problem as a bi-level hierarchical problem, where the minimization of the delay of the preferential ITs is given higher priority in the hierarchy compared to the minimization of the total service time of all ITs. As exact solution algorithms that can be used to efficiently solve these problems do not exist, a genetic based and a k-best based algorithm are proposed. The rest of this paper is summarized as follows. The next section presents a brief description of the bi-objective and bi-level optimization problems. The next two sections present two mathematical formulations and the description of the solution algorithms. The following section presents and
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