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Scheduling trucks in cross-docking systems: A robust meta-heuristics approach

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A B S T R A C T

In a cross-docking system, trucks must be scheduled to minimize the total flow time of the system. This problem is NP-hard, and this study proposes two hybrid meta-heuristics—hybrid simulated annealing and hybrid variable neighborhood search—to solve it by achieving the best sequence of truck pairs. The Taguchi method serves to reveal the best robustness of these algorithms. To demonstrate the effectiveness of the proposed methods, especially for large-sized problems, this study solves various test problems, and the computational results clearly reveal that the proposed methods outperform previous approaches.

1. Introduction

A typical modern warehouse is a dynamic, intelligent distribution center (DC) in which products and packages are processed in real-time and moved in and out on schedule. These dynamic and intelligent warehouses also tie together all distribution and logistic functions, with minimal inventory storage. Inputs and outputs must be regulated precisely and streamlined in an intelligent manner.

Therefore, the distribution environment aims to make operations ever more efficient. Companies can cut costs by reducing inventory at every step of the operation, including distribution. At the same time, customers demand better services, which translate into more accurate and timely shipments. Instead of waiting a week to receive a product, most customers want delivery in 1 or 2 days. In most manufacturing environments though, it is difficult to ship directly from the manufactures to the customer, so intermediate points are necessary to connect them. One such intermediate point in a supply chain system is the DC.

Distribution center operations consist of five basic functions: receiving, sorting, storing, picking, and shipping. If cooperation among these five elements improves, the DC can reduce costs and improve productivity. However, the best way to reduce costs and improve efficiency is not simply improving a function but rather eliminating it if feasible. In this context, cross-docking offers the potential of eliminating storage and picking, the two most expensive warehousing operations. This method of distribution management also helps companies better control their distribution operations, because it represents a material handling and distribution concept in which items move directly from the receiving dock to shipping dock, without

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ever being stored. The primary objectives of a typical cross-docking system thus are to eliminate storage and excessive material handling.

Cross-docking applies to both manufacturing and distribution functions (Schwind, 1996), and virtually all warehouses and DCs perform at least some cross-docking. In a manufacturing plant, the finished product usually moves from the packing point to storage, whereas with cross-docking, the product travels directly from packaging to shipping, and sometimes directly into waiting trucks. In a DC, cross-docking can involve most or all of the materials that arrive at the receiving dock. In general, cross-docking seems to work best for companies that either distribute large volumes of merchandise or serve many stores. Through their ability to handle a high volume of items in a short amount of time, cross-docking systems lead to increased inventory turnover, lower inventory levels, greater customer responsiveness, and better control of the distribution operation. Moreover, cross-docking can play an important role in supply chain operations, in that it shortens total transfer time and transportation lead-time, in support of other supply chain activities such as just-in-time (JIT) provisions, made-to-order supplies, and merge-in-transit strategies.

However, scheduling cross-docking systems remains a challenge. We propose two hybrid meta-heuristic algorithms—hybrid simulated annealing (HSA) and hybrid variable neighborhood search (HVNS)—to address this concern and test them using sample problems that highlight their effectiveness compared with each other, with heuristic methods, and with tabu searches that exist in prior literature. Moreover, we explore the impact of fine-tuning the parameters related to the performance of the HSA and HVNS with a Taguchi optimization technique, as often used in quality engineering to enhance the robustness of an experimental setup (Eddie et al., 2006). The Taguchi method also offers a cost-effective and labor-saving means to investigate several factors simultaneously and identify those that have primary impacts in a minimum number of possible experiments (Al-Aomar, 2006). Previous studies apply this approach successfully during the parameter design stage to establish optimum process settings in various fields (Caprihan and Wadhwa, 2005; Cheng and Chang, 2007; Luo et al., 2008).

In the next section, we offer a brief literature review of cross-docking problems. We then explain the definition of the problem in Section 3. In Section 4 we present the solution procedure by providing an overview of heuristic methods and discussing applications of the tabu search to the problem and elaborating on the procedural implementation of our proposed algorithms. The Taguchi method, which analyzes the results achieved by our proposed algorithms and comparative analogy between algorithms, appears in Section 5. In Section 6 we discuss this paper's issue and then the summary of the paper is presented in Section 7. Finally, we conclude with some implications and suggestions for further research.

2. Literature review

One of the earliest technical papers on cross-docking systems, by Rohrer and Matthew (1995), outlined modeling methods and issues as they apply to cross-docking systems. That study also described how simulation could help ensure success in system designs by determining the optimal hardware configuration and software controls, as well as establishing failure management strategies before the cross-docking problems arose. Although Rohrer notes some modeling methods and issues for cross-docking systems, he does not discuss any implementation issues. Mosheiov (1998) addresses the pickup and delivery problem. A kind of vehicle routing problem, with a mathematical model that minimizes transportation costs and maximizes vehicle efficiency.

Subsequent research proposed two heuristic algorithms that could find good solutions in a reasonable amount of time. Barbarosoglu and Ozgur (1999) argue that because vehicles allocated to a certain DC take charge of an exclusive area, optimal transportation planning with multiple delivery centers in the supply chain could be replaced by multiple sub-optimizations that involve the optimization of transportation planning with one delivery center. Moreover, they propose a heuristic algorithm based on a neighborhood algorithm and a tabu search algorithm. Apte and Viswanathan (2000) instead offer a framework for understanding and designing cross-docking systems, including techniques for improving the overall efficiencies of logistics and distribution networks. Their framework and techniques derive from a review of previous literature and an investigation of warehousing practices during several field visits. Thus, they present issues related to the network structures used for warehousing, the design of physical and information flows in cross-docking, and analysis and management systems. Lau et al. (2003) also use a tabu search algorithm to minimize the transportation costs for vehicle routing during specified time windows and for a finite number of vehicles. Bartholdi and Gue (2004) study the best shape for a cross-docking system and find that though docks in the shape of an I, L, or T are most common, other unusual shapes include those that look like a U, H, or E. To determine the best shapes, they conduct computational experiments and evaluate each shape by varying the system's characteristics and recording a surrogate for the expected labor cost. As they show, the best shape for a cross-docking system depends on the size of the facility and the pattern of freight flows within it.

To study a central problem for cross-docking, namely, eliminating or minimizing storage and order picking activity using JIT scheduling, Li et al. (2004) design and implement two heuristics and thereby solve the NP-hard problem for real-time applications. The first heuristic uses squeaky wheel optimization, embedded in a genetic algorithm; the second uses linear programming within a genetic algorithm. In two studies, Lim et al. (2006a,b) consider truck dock assignment problems with time windows and capacity constraints in the transshipment network. They first formulate an integer programming model and propose a tabu search and a genetic algorithm, and then, to minimize the operational cost of the cargo shipments and the