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Invited Review

Synchronization in cross-docking networks: A research classification and framework

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ABSTRACT

Cross-docking is a distribution strategy that enables the consolidation of less-than-truckload shipments into full truckloads without long-term storage. Due to the absence of a storage buffer inside a cross-dock, local and network-wide cross-docking operations need to be carefully synchronized. This paper proposes a framework specifying the interdependencies between different cross-docking problem aspects with the aim to support future research in developing decision models with practical and scientific relevance. The paper also presents a new general classification scheme for cross-docking research based on the inputs and outputs for each problem aspect. After classifying the existing cross-docking research, we conclude that the overwhelming majority of papers fail to consider the synchronization of local and network-wide cross-docking operations. Lastly, to highlight the importance of synchronization in cross-docking networks, two real-life illustrative problems are described that are not yet addressed in the literature.

1. Introduction

Four commonly used strategies to configure a firm's distribution activities are direct shipment, milk-runs, warehousing, and cross-docking. In a direct shipment strategy, each shipment is sent directly from origin to destination. A milk-run strategy groups shipments into routes visiting multiple origins and destinations sequentially. These two strategies are associated with low implementation costs as they do not involve intermediary logistics facilities. When shipment sizes are small and customers are geographically dispersed, a direct shipment or milk-run strategy results in partially empty trucks and longer transportation lead times as products are stored further away from their demand points. In response to these shortcomings, firms can employ a warehousing or cross-docking distribution strategy.

Warehousing enables the consolidation of shipments to customers by assembling full truckloads from the products stored in a *warehouse* or *distribution center*. Storage can be efficiently replenished by ordering full truckloads from suppliers. At the warehouse, the main operations are to unload inbound trailers with products from suppliers, store the products, retrieve products and assemble them for shipment upon customer order, and dispatch the consolidated loads onto outbound trailers (Gu, Goetschalckx, & McGinnis, 2007). The existence of a storage buffer allows local warehouse operations to be considered largely in isolation from activities elsewhere in the distribution network. Hence, warehousing literature primarily addresses local warehouse problems (see, e.g., De Koster, Le-Duc, & Roodbergen, 2007; Gu et al., 2007; Gu, Goetschalckx, & McGinnis, 2010; Rouwenhorst et al., 2000).

Instead of moving partially empty trailers or assembling loads from storage, a cross-docking strategy groups shipments from multiple adjacent origins into full truckloads, which are then send to a *cross-dock* where they are unloaded and immediately recombined with loads sharing the same destination (Bozer & Carlo, 2008). As a result, cross-docking can realize transport efficiencies at reduced material handling and storage costs by eliminating the storage and order picking activities from the main warehouse operations (Apte & Viswanathan, 2000; Gue, 2007). An important implication of employing a cross-docking strategy is that local operations at the cross-dock are tightly coupled with distribution activities elsewhere in the supply chain due to the absence of a storage buffer (Vogt, 2010). Therefore, the design and coordination of cross-docking operations requires a holistic approach, which aims to synchronize local and network-wide operations.

Decision models for the design and coordination of cross-docking operations are proposed in a considerable and fast-growing base of literature. Four recently published papers review this literature. Boysen and Fliedner (2010) focus on one important cross-docking problem, i.e., the scheduling of trailers at the cross-dock.

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Agustina, Lee, and Piplani (2010), Stephan and Boysen (2011a) and Van Belle, Valckenaers, and Cattrysse (2012) present broader literature reviews. In these reviews, cross-docking literature is discussed by considering groups of papers addressing a similar decision problem – ranging from strategic design to operational planning. Despite the inherent interdependencies between local and network-wide cross-docking operations, none of the existing review papers discusses how different decision problems are actually related. The primary objective of this paper is to fill that gap and advance from an understanding of solving isolated problems to an appreciation of the challenges inherent to solving cross-docking synchronization problems. To that end, this paper presents a framework for synchronization in cross-docking networks, which is based on a general classification of cross-docking research.

This paper is organized as follows. Section 2 presents our conceptualization of cross-docking. Section 3 defines six cross-docking problem classes and lists their constituent decision problems. A review and classification of cross-docking research is presented in Section 4. The research classification is used to understand the information needs for, and outputs from, each problem class. Based on this understanding, the framework for synchronization in cross-docking networks is proposed in Section 5. Section 6 demonstrates how the research classification and framework can be used to identify cross-docking synchronization problems with practical and scientific relevance. Lastly, Section 7 presents our conclusions.

2. Conceptualization

Many different definitions of cross-docking can be found in literature. A review thereof reveals three common defining elements. Firstly, cross-docking definitions often contain a description of the basic operations performed at the cross-dock. In essence, incoming products are unloaded from inbound trucks, sorted based on their destination, moved through the cross-dock, and immediately dispatched onto outbound trucks. Secondly, most cross-docking definitions include a specification of the typical constraints and objectives associated with operations at the cross-dock. The most typical constraint in that regard is the limited time products stay inside the cross-dock, e.g., 24 hours. The aim for minimal material handling and the intention to limit the waiting times or tardiness of trailers and products at the cross-dock are frequently mentioned objectives. Thirdly, several cross-docking definitions address the purpose of a cross-dock in the distribution network. An important purpose of a cross-dock is to enable the consolidation of multiple less-than-truckload shipments to realize economies in transportation costs. At the same time, the rapid transshipment of products at the cross-dock should enhance distribution responsiveness.

In this paper, we emphasize the importance of including a broader network orientation when defining and conceptualizing cross-docking. Accordingly, our conceptualization of cross-docking considers local and network-wide cross-docking operations. *Local cross-dock operations* are conceptualized as the operations performed at the cross-dock; *network-wide cross-docking operations* as those performed elsewhere in the cross-docking network. We define a cross-docking network as the subsystem of a supply chain formed by one or more cross-docks, their inbound and outbound transport routes, and the stakeholders connected to the cross-docks by means of those routes. Various logistics facilities are identified as potential stakeholders in cross-docking networks. These logistics facilities include the typical supply chain entities (e.g., suppliers, manufacturers, warehouses, distribution centers, retailers, and customers) and can be located at the inbound and outbound side of the cross-dock. Below, we present a characterization for different cross-docking network configurations and address some industry specific implementations of cross-docking. For a comprehensive industry-oriented introduction to cross-docking, the reader is referred to Napolitano (2000).

Fig. 1 presents three typical configurations for cross-docking networks with a single cross-dock. Cross-docks in a *many-to-few network configuration* are often encountered in a manufacturing context, e.g., the automotive industry. Raw materials and components from many suppliers are consolidated at the cross-dock and sent to one of few nearby located manufacturing plants. The main purpose of the cross-dock in this setting is to enable a just-in-time supply of readily usable materials to the manufacturer. Accordingly, value added logistics activities are often performed at the cross-dock in preparation of the manufacturing operations. Due to the importance of cross-docks in these supply networks, manufacturers often invest in the automation of local cross-dock operations.

A *few-to-many network configuration* is common for cross-docks in retail distribution. At the cross-dock, incoming truckloads from a few distribution centers are split into delivery loads for a large number of retail stores. The cross-docking strategy of retailers usually originated from opportunistic cross-docking, i.e., products bypassed the storage facilities at distribution centers only if the opportunity occurred. Many retailers have developed their opportunistic cross-docking into a strategy purposely processing large cross-docking freight flows, which are handled at a dedicated cross-dock area inside a distribution center. Operations at retail cross-docks are fully geared towards a reduction of inventory and distribution costs – while maintaining or improving responsiveness. The material handling systems inside retail cross-docks often allow for in-batch movement of shipments, since products are placed onto homogeneous load-carriers, e.g., rolling containers.

A *many-to-many network configuration* is common for cross-docks in the less-than-truckload and parcel delivery industries. Parcel delivery companies transport many relatively small-sized packages, which allows an automated conveyor system for material handling inside the cross-dock. By contrast, the larger sized and strongly varying shapes of products through the cross-docks of less-than-truckload carriers necessitate a flexible material handling system – typically formed by manually operated forklift trucks.

Fig. 2 shows two prototypical network configurations including multiple cross-docks. In cross-docking networks with a *single layer of cross-docks*, shipments are often allocated to one of the cross-docks. Moreover, opportunities can be sought to transport the shipment directly from origin to destination, i.e., bypassing all

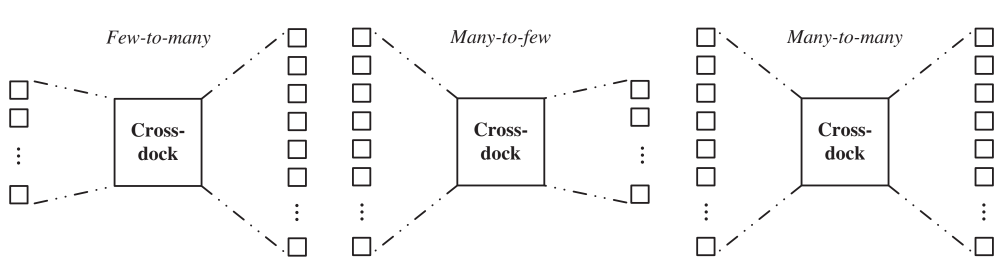

Fig. 1. Network configurations with a single cross-dock.