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Layout and control policies for cross docking operations

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ABSTRACT

Many supply chains strive to shorten the time between a customer's order and the actual delivery of the ordered goods. Cross docking is one of the options to reduce these response times. Cross docking facilities are dynamic environments where products arrive and leave the same day. To deal with these dynamic aspects, the need for efficient control policies in combination with flexible and easy to reconfigure storage area layouts increases. We present a dynamic design methodology to select control policies and determine layout rules for cross docking facilities. We present both advantages and disadvantages of the proposed layout procedures. We use the cross docking center of the "Royal Horticultural Company Lemkes" in The Netherlands as the basis for a comparative analysis of the procedures presented. We show that, by applying our design methodology, a savings of 16% can be obtained in total travel distances of employees.
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1. Introduction

Regardless of the supply chain – mobile phones or groceries – the goal is generally the same: to shorten response times. Response times consist of production, handling and waiting times. The reduction of response times is increasingly important from the perspective of cost reductions and customer service improvement (De Treville, Shapiro, & Hameri, 2004). Any of the three components of response time are fair targets for reduction. An important reason for the occurrence of waiting time in supply chains is the storage of products in warehouses. A very large reduction of waiting time in the warehouse – from weeks or days to just hours – can be obtained if loads from incoming trucks are directed to departing trucks with (almost) no storage in-between. Loads can be stored on the floor between unloading and loading for a few hours to wait for a truck to pick them up. This concept is called *cross docking* (Schaffer, 1998).

Usually, the storage time in cross docking is less than 24 h (Yu & Egbelu, 2008). Obvious candidates for cross docking are products that have already been ordered by the final customer before transportation from the manufacturer to the warehouse has started. Other candidates for successful cross docking are products with short delivery times, products with high demand and products with highly predictable demand (Richardson, 1999). A cross docking facility is usually part of a larger distribution network in which trucks operate (e.g., Musa, Arnaout, & Jung, 2010). A cross docking facility typically consists of a number of dock doors, where trucks can load or unload. Each arriving load that cannot be directly transshipped to another truck is stored in a storage area. The typical storage area for a cross docking center consists of an open area where loads can be stored on the ground. Sometimes, loads may be stored on top of each other, or racks may be used. In any case, loads must be easily accessible, because the time before departure is so short. In this paper, the main question is how to design the storage area for cross docking such that handling and waiting times are reduced.

In general, the design of a facility includes many aspects. Very roughly, we may distinguish three phases in designing facilities. The first phase consists of determining the block layout, which places the various areas within the facility (e.g., Aiello, Enea, & Galante, 2002; Meller & Gau, 1996). For cross docking facilities the main areas to position are the dock doors and the storage area. The second phase consists of determining the detailed layout of each of the areas. The third phase consists of finding control policies to control the processes both at a facility level as well as for separate areas. Although often presented as a top-down approach, it is important to acknowledge that the three phases influence each other. Meller, Kleiner, and Nussbaum (2004) recommend modeling constructs that merge the area design (second phase) into the block layout design (first phase). Roodbergen, Sharp, and Vis (2008) show the interplay between the optimal layout (second phase) of an order picking area and the control policy (third phase) used in the optimization procedure. It may therefore also be important for cross docking facilities to take the control policies (third phase) into account while designing the layout of each area (second phase).

A good layout for the storage area of a cross docking center allows easy access to the loads and fast transportation of the loads to

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the loading dock. It seems therefore reasonable to focus on travel distance minimization. The travel distance in cross docking facilities depends on the layout, but also on the control policies. So far, the issue of determining the layout of a storage area in a cross docking facility while concurrently taking the selected control policies into account has not been studied in literature as will be shown in Section 2. The objective of this paper is to derive a dynamic design methodology and several layout procedures which can solve the decision problem of determining an efficient layout for the storage area, while taking the selected control policies into account.

In Section 2, we present some background information on designing storage areas in cross docking facilities. Section 3 proposes a design methodology that determines the layout of a storage area given selected efficient control policies. Main components of the methodology are several layout procedures. In Section 4, we derive these layout procedures varying from fixed layouts to flexible layouts that can be changed on a daily basis. Furthermore, we present advantages and disadvantages for each of these methods. In Section 5, we apply the methodology in a proof of concept to design the cross docking operation for houseplants of the "Royal Horticultural Company Lemkes" in The Netherlands. Section 6 includes our conclusions.

2. Design of cross docking facilities

While the field of cross docking has seen significant interest in the past 10-years, from both a practical and theoretical standpoint, the literature on cross dock design and layout remains limited. Many cross docking articles focus solely on the operations and scheduling aspects of a "standard" cross dock facility – without considering the integration of layout design with operational policy. We begin our review by highlighting the operational considerations that make up cross dock control policies. We then continue with a review of the literature on cross dock layout. Although the different operations in a cross docking facility are simple in nature, the planning issues that exist are complex. Therefore, logistics managers are in search of efficient and flexible design methods and control policies to regulate all processes to minimize response times.

In general, two conceptually different product flows may exist in a cross docking facility. First, unit loads (such as pallets or carts) may arrive at the cross docking facility that will leave the facility unaltered for delivery to customers. These loads arrive at the inbound dock doors and can either be transshipped directly to the outbound dock doors or stored temporarily in a storage area. Second, unit loads may arrive at the facility that need to be split for delivery to multiple customers and/or combined with parts of other unit loads for delivery to the same customer. In this case the operational processes are more complex.

The process of regrouping incoming loads into shipments that match customer orders in a cross docking facility is conceptually quite different from the corresponding process in a warehouse. The main reason for the difference stems from the fact that in a warehouse products are stored and wait (for days or weeks) for a customer to order them. In contrast, in a cross docking environment, the destinations of all products are already known when they arrive at the facility. Stated differently, in a warehouse the stored products are known and the moment at which the customer's order arrives is unknown; while in a cross dock environment, the product arrival is unknown, but the departure times are known. The matching logic of the warehousing process is that the products are stored at fixed locations and when an order arrives an employee moves to the location to retrieve that product for the customer (manual order picking). In a cross docking facility, in contrast, receptacles (e.g., carts or pallets) for each known customer order are positioned at predefined locations, and when the products arrive, the products are taken from the arriving receptacle and put into the pre-positioned receptacles for the respective customers.

The regrouping process at a cross docking facility is, in many ways, the inverse of the order picking process at a warehouse. In a warehouse, the employee starts with an empty cart (or pallet), moves through the area while putting products onto the cart, and ends with a full cart that goes to the customer. In cross docking, the employee starts with a full cart, moves through the area while taking products off the cart, and ends with an empty cart; the pre-positioned receptacles then go to the customers. In both situations, the design of the storage area directly influences the performance of the facility as measured by the travel distances of employees. The primary difference being that the layout in cross docking is formed by moveable receptacles (cart or pallets) that can be reconfigured every day. This reconfiguration can be done at almost no additional cost since the storage area is empty at the end of every day (the cart or pallets have been shipped to the customers). This is in sharp contrast with the warehouse layout that consists of fixed racks that may stay the same for years.

The existing literature on cross docking primarily focuses on planning problems. More specifically, most authors study the problems of sequencing inbound and outbound trucks at the cross dock facility and the assignment of those trucks to dock doors. A recent overview paper of Boysen and Fliedner (2010) presents a classification of methods available for truck scheduling for cross-dock settings. For both problems, the objective is to perform all facility operations as efficiently as possible. Yu and Egbelu (2008) propose a mathematical model and heuristics to simultaneously consider the assignment of products to outbound trucks and the sequencing of inbound and outbound trucks to dock doors. Vahdani and Zandieh (2010) propose several meta-heuristic algorithms to schedule trucks such that total operation times in the facility are minimized. The authors do not study the processes that occur within the facility. The dock door assignment problem is studied by Tsui and Chang (1990) and Tsui and Chang (1992). The main performance measure in these papers is the total travel distance of employees in the facility. In addition to minimizing travel times, Bartholdi and Gue (2000) used a second objective, in their simulated annealing approach to assign outbound trailers to doors, namely minimizing the waiting times that occur due to congestion. Miao, Lim, and Ma (2009) examine dock door assignment problems while considering time window constraints for trucks. They present a mathematical model and meta-heuristics to assign trucks to doors such that both the costs and the number of unfulfilled shipments are minimized. Another planning problem consists of the overall layout of the cross docking facility. Bartholdi and Gue (2004) show that the shape of the facility directly influences efficiency and costs. The most efficient type of overall layout varies with the size of the facility. As mentioned except for the overall layout also attention has to be paid to the specific layout of each of the areas within the facility. In warehousing literature this is a more common topic (see for an overview, De Koster, Le Duc, and Roodbergen (2007)). We found no literature that specifically deals with the layout of the storage area in a cross docking facility.

Two important operational problems in cross docking facilities include the routing of employees through the facility to store unit loads or to redistribute products over the storage locations and the assigning of locations to orders. Routing policies determine the sequence in which various locations in the area must be visited. In the literature, routing policies are mainly studied in the context of order picking processes in warehouses. The objective of routing policies is to sequence the orders on a single distribution list, such that an efficient route is obtained through the locations in blocks of

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