Implementing a Cross-Docking System in a Warehouse – A Systematic Review of Literature

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Abstract

Nowadays, many firms try to delight their customers by reducing the time between customer order and the time of delivery. Due to this reason, cross-docking has become an interesting logistics strategy in supply chains. In this process, arrival and the departure of cargo will be taken place on the same day. This study has been carried out to identify the processes involved in cross-docking, its benefits, complexities of implementing a cross-docking system and the factors to consider when implementing a cross-docking system. A comprehensive literature review has been conducted along with expert reviews based on interviews in order to address the identified research gap. The previous studies were analyzed to select the studies that have studied the implementation of cross-docks and the significant factors of a cross-docking operation. Then, a full-text review was conducted to identify the factors that are necessary to consider when implementing a cross-docking system in a warehouse. Based on the literature, cross-dock shapes that are suitable for respective cross-dock types have been suggested.

Keywords: Cross-docking, implementation, warehouse

1. Introduction

With the development of a customer-driven economy, supply chains attempt to satisfy customers by delivering goods and services with a minimal time while minimizing the material handling expenses. As a result of increasing pressure on supply chain partners to optimize operations, cross-docking has turned into a prominent method for the transportation of materials. Rather than a single driver takes care of many separate deliveries; these can be mixed or re-sorted out at a close distribution centre which will enhance the driver effectiveness**.** As a rule, when a shipment is landed at the port, it has to be moved to the distribution centre. In cross-docking, when the materials are unloaded from the inbound trucks, it will be sorted and moved to the outbound truck which is scheduled to be delivered to a particular destination. This is advantageous for the customer by delivering materials on the scheduled time and as well as for the manufacturer by diminishing warehouse expenses and time.

Figure 1 shows the design of a typical cross-dock terminal. When the inbound trucks arrive and inbound docks are occupied, they will be assigned to the waiting area for inbound trailers in order to wait to be worked. Once the due time arrives; the vehicle is asked to be located to the dock to start the unloading process. When the unloading process is over, shipment is checked and sorted for the relevant destinations. Then, the cargo will be moved to a temporary staging area which is close to the outbound docks manually with the support of material handling equipment (four-wheeled platform dollies, pallet jacks, forklift movers etc.). At the temporary staging area; value-added services like labelling will be processed. As soon as the outbound vehicle is available at the outbound dock; cargo will be loaded to it to be delivered to the final destinations (Novaes et al, 2017).

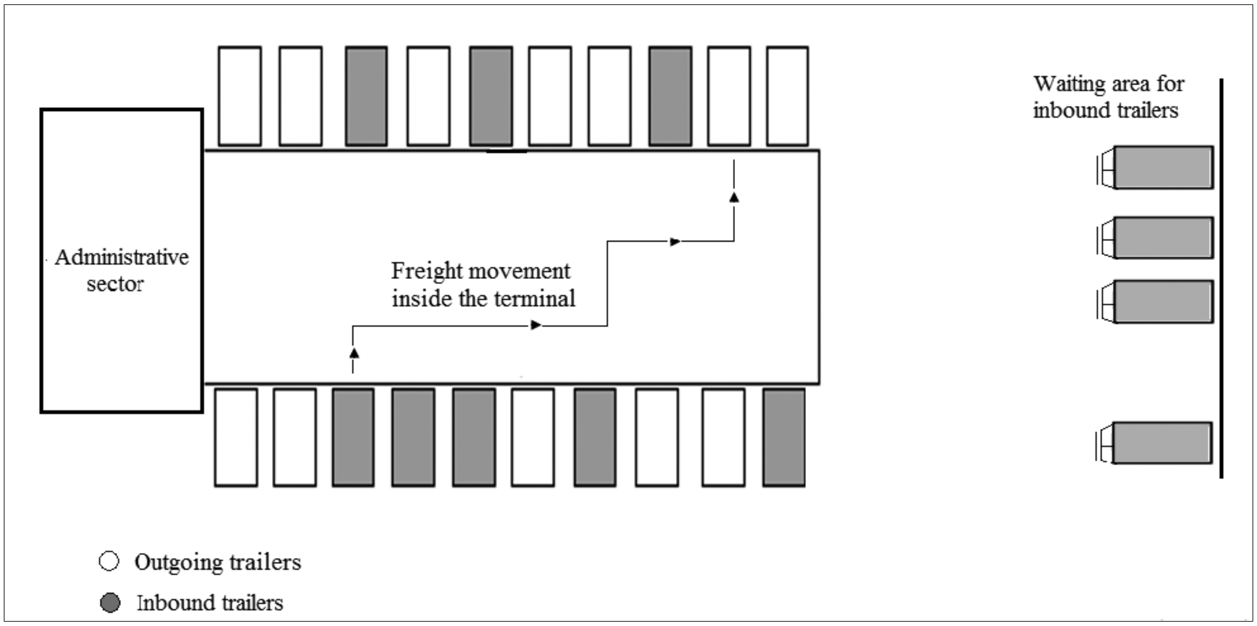

Figure 1 Design of a typical cross-dock terminal (Novaes et al, 2017)

1.1 Definitions of cross-docking

In the cross-docking strategy, products arrive at the retailer DC from the suppliers, are transferred to vehicles serving the stores and are then delivered as quickly as possible (Benrqya, 2019)

A definition for cross-docking provided by Kinnear (Kinnear E. 1997) is: ‘‘receiving a product from a supplier or manufacturer for several end destinations and consolidating this product with other suppliers' product for common final delivery destinations’’. As per the definition, the focus is on the consolidation of shipments to achieve economies in transportation costs.

Cross-docking is a lean warehousing strategy with numerous advantages such as no or very few inventory levels, low transportation costs due to product consolidation, increase in product flow speeds and so on. Materials arriving in a cross-docking warehouse from different destinations are unloaded from the inbound trailers, sorted according to their destinations, repacked with other products if necessary and reloaded into the outbound trailers. All operations take place within 24 hours in general (Alpan et al 2011).

Cross-docking is a common practice used by companies to reduce warehousing and transportation costs associated with shipments of different items from multiple origins to multiple destinations (Konur and Golias 2012).

1.2 Benefits of using Cross-Docks

The cross-docking distribution strategy has advantages over traditional warehousing because it reduces inventory costs, storage space and handling costs. It also accelerates cash flow and minimizes cycle times due to the elimination of a storage point in the supply chain (Kumar, 2008).

Cross-docking allows the efficient consolidation of products, decreases inventory by eliminating storage and fastens the flow of materials which will result for more frequent deliveries. The fastened flow of materials will reduce inventory obsolesce. Also, it increases the handling capacity of the warehouse with the minimum use of warehouse facility (Ertek 2005)

Furthermore, gains such as cost reductions (warehousing costs, inventory-holding costs, handling costs, transportation costs, labour costs), improved resource utilization, a better match between shipment quantities and actual demand and better control of the distribution operations make cross-docking an interesting logistics strategy (Belle et al 2011).

The supply chain with a cross-dock can produce an effective, consistent delivery which will reduce supply chain costs, improve customer satisfaction, and enhance the marketing advantage, with its attendant increase in loyalty and potential sales (Vogt 2004).

1.3 The appropriateness of cross-docking

The process of cross-docking will not suit every warehouse's need; therefore, it is important to make an informed decision as to whether cross-docking will increase the productivity, costs and customer satisfaction for your specific business. Cross-docking can advance the supply chain for a variety of specific products. For one, unpreserved or temperature controlled items such as food which need to be transported as quickly as possible can be benefitted by this process. Additionally, already packaged and sorted products ready for transportation to a particular customer can become a faster and more efficient process through cross-docking.

Geoffrey Sisko has suggested that the products that are with predictable, high demand and high cubic volume flow, and perishable products are ideal for cross-docking (Aichlmayr, 2002).

Cross-docking will not result in better results if there is an imbalance between the incoming load and the outgoing load. Hence, the goods that are less stable (e.g.: grocery and regularly consumed perishable food items) or goods that have demand rates that are more; are the most suitable to be cross-docked. Since cross-docking minimizes the level of inventory at the warehouse there is a probability of being stock out. If the unit stock-out cost is low; it can be gained more with the cross-docking strategy. (Belle et al, 2011)

2. Complexities of implementing a cross-docking system

There are some challenges when shifting from a traditional warehouse and executing a new cross-docking terminal.

2.1 Resource limitations

Space limitations- If the cross-docking design is implemented inside the existing warehouse; space that can be used for the cross-docking terminal is limited. On the other hand, inbound vehicles require parking space when waiting for the time of unloading (Novaes et al, 2017).

Workforce limitations – Cross-dock terminal will be more labour intensive since cargo must be sorted and moved quickly to relevant destinations. From the four main activities: receiving, storing, order picking and put away; order picking is more labour intensive. Thus, a worker will be required to provide training on the order picking in order to perform the activities quickly in the cross-dock to reduce the waiting time (Belle, 2011). Quality control activities that may require to carry out during this process may increase the requirement of the workforce (Ertek, 2012).

Limitations of Material Handling Equipment- Operation of cross-docking needs adequate material carriers within the warehouse. Searching for material handling equipment as required and investing on them is another limitation when implementing a cross-docking system in the warehouse.

2.2 Poor Cross-dock design and layout

The design of the cross-dock terminal plays a major role when performing activities while reducing transportation costs, labour costs etc. The design solely based on the warehousing principles for example in some cases high roofs for storage cannot be used in cross-dock. When considering storing food items; there are two main types as frozen food and food under the room temperature. When handling both of these, there will be a negative impact on one another if both placed adjacently. A poor cross-dock design reduces the capacity of the facility and its effectiveness (Vogt, 2004).

The efficiency of the cross-dock with regard to physical layout is determined by measuring the total travel distance with mass moved within the facility for all the goods. Thus the mass-distance moved is equivalent to the total work done in the facility and the design must try to minimize this value (Vogt and Pienaar, 2010).

2.3 Poor operational competences and management

For effective operations management within the cross-dock; effective information flow is a necessity. For example, "Wal-Mart operates a private satellite communication system that sends point-of-sale (POS) data directly to Wal-Mart's 4,000 vendors" (Stalk, 1992)

Also, inventory stockouts affect cross-docking operations negatively. Therefore, operational decisions must be interrelated for better material flow in the supply chain (Ertek, 2012). The service model of the cross-dock regulates the degree of freedom in assigning inbound and outbound trucks todock doors. Service mode is of three types as exclusive, mixed and combination mode whereas in exclusive mode each dock door is either exclusively dedicated to inbound or outbound vehicles, inbound and outbound vehicles are processed at all doors in mixed mode and these two will be combined in the combination mode (Boysen and Fliedner, 2010).

Furthermore, temporary storing and performing value-adding activities needs to be performed smoothly in order to result in cross-docking effective. The poor performance of these operations reduces the efficiency of the cross-dock operation ultimately the supply chain.

3. The characteristics of a good cross-dock

As described in the IARW (International Association of Refrigerated Warehouses) operating manual; the characteristics of an ideal cross-dock are;

- Suppliers who have the right processes in place so they can consistently provide the correct quantity of the correct product at the precise time when it will be needed;
- Time accurate, preferably paperless information flow among trading partners and a continuous product flow that is matched to actual demand;
- An appropriate network of transportation, facilities, equipment and operations in place to support the flow of the product from the supplier through the cross-dock facility to the customer;
- Personnel who recognize the urgency of moving product rather than storing it. They consistently track performance to determine strengths and weaknesses and
- Accurate data and realistic forecasts.

4. Implementation of a cross-dock

This section discusses the factors necessary to consider when implementing a cross-docking system in a warehouse. These mainly include the type of cross-dock, shape of cross-dock, material handling within a warehouse, truck scheduling.

4.1 Type of cross-dock

In the study of Implementing a cross-docking system carried out in 2000; Napolitano has described different types of cross-docking systems as follows. (Napolitano, 2000)

Type 1: Pre-allocated supplier consolidation: The destination is determined at the supplier in here.

Type 2: Pre-allocated cross-docking operator (CDO) consolidation: In this type of cross-docking system, the product is post allocated and destination is determined at the cross-dock facility.
Type 3: Post-allocated cross-docking operator consolidation: When supplier consolidation happens, the supplier builds the finalized pallets that will be shipped to the final destinations. When cross-docking operator consolidation happens, the final pallets are built by the cross-dock operator at the cross-dock facility.

The above categories have been categorized based on the place of allocation of the products.
From the study done by Benrqya; shows two types of cross-docks as pick-up line cross-docking where the and the sortation of goods is done at the retailer distribution centre level and pick-up by store cross-docking where the allocation and sorting of materials is done in supplier distribution centre level (Benrqya,2019)

Another classification of cross-docks has been done based on the segments of the supply chain type of operation serves and it is as follows Vogt, 2004).

- Manufacturing cross-docking - receiving and consolidating inbound suppliers to support Just in Time manufacturing;
- Distributor cross-docking - consolidation of multiple suppliers into a consolidated load or consignment for delivery (may include merging in transit), which is scheduled for delivery as soon as the consignment is complete;
- Transportation cross-docking - consolidation and de-consolidation to make the transport as efficient as possible,
- Retail cross-docking - consolidation of multiple suppliers into a consolidated load for delivery to a store and
- Opportunistic cross-docking - transfer of an item across- from receiving to dispatch docks.

It is vital to identify the appropriate type of cross-dock when implementing a cross-docking system to schedule activities in order to gain maximum efficiency.

4.2 The shape of the cross-dock

The shape of the cross-dock design also plays an important role in increasing the throughput of the operations. Several studies have identified different shapes for cross-docks and their effectiveness.

The shape of the cross-dock can be defined by the letter corresponding to the shapes I, L, U, T, H, E.

As per the experiments; I-shape is the most effective for smaller cross-docks (fewer than about 150 doors). A T-shape is best for intermediate size and for more than 200 doors (approximately) an X-shape is appropriate. Cross-docks with a T or X-shape have a greater `centrality'. However, they achieve this at the cost of additional corners which reduce the labour efficiency (2 inside and 2 outside corners for T, 4 inside and 4 outside corners for X). An inside corner renders some doors unusable, while doors around an outside corner have less floor space available to stage freight. So, these additional corners are a fixed cost, which begins to pay off for larger docks. It is however not always easy to predict which shape is better, because this also depends on e.g. the freight flow pattern (Belle et al, 2011).

In the analysis of best shape for a cross-dock; I shape has been chosen as an ideal shape for a cross-dock. The reasons for selecting shape I is that this allows moving the cargo directly across- the dock from inbound door to the outbound door. Also, the dock is narrow in this shape which reduces the labour costs (Bartholdi and Gue, 2004).

The shape of the terminal determines the layout of the doors and thus, the travel distance of the cargo movers. This makes an effect on the congestion level, such as narrow docks provide fewer areas for movers to move around (Wong and Shuet, 2009).

4.3 Warehouse Operations Optimizations

Several mathematical models have been discovered to find the optimal freight flow in the cross-dock.

In the study done by Li et al in 2004; a model has been proposed based on Just In Time (JIT) scheduling to minimize the storage time and order picking activity. They developed Integer Programming (IP) model that objective is to minimize the total penalty of earliness and tardiness in an incoming and outgoing container. They proposed a meta-heuristic procedure to solve the problem (Li et al, 2004).

A genetic algorithm has been proposed by Mcwilliams et al in 2005 in the study of the parcel hub scheduling problem to determine the schedule of a trailer in the unloading dock. This has been modelled as a linear programming model (McWilliams et al, 2005).

In 2007, Larbi et al. have studied the scheduling of transshipment operation inside the cross-docking to minimize the total inventory holding cost and truck replacement cost. This model considers that the facility has one stack and one inbound and outbound door. The problem has been depicted as a graph-based model and solution has been derived using short path methodology (Larbi et al., 2007).

In the model proposed by Tsui and Chang in 1990, the dock door assignment has been done with the objective to minimize the travel distance of the forklifts (Tsui and Chang, 1990). This assignment problem has been extended by Tsui and Chang in 1992 to solve the model using a microcomputer-based tool based on bi-linear programming (Tsui and Chang, 1992).

Oh et al. in 2006 has proposed a model for assigning the destinations to doors in the cross-docking system of a mail distribution centre. The nonlinear problem has been developed with the objective of minimizing the travel distance of the pallets (Oh et al., 2006).

A layout design model has been proposed by Bartholdi and Gue with the objective to develop an optimal layout by assigning of the dock doors well. The objective of this model is to minimize the cost by minimizing travel time and material handling (Bartholdi and Gue, 2000).

4.4 Truck scheduling

Numerous truck scheduling models have been developed by authors to truck scheduling in the cross-docking network. Ley and Elfayoumy have proposed a genetic algorithm to solve the problem of scheduling of inbound and outbound truck to minimize the distances (Ley and Elfayoumy, 2007). Shakeri et al has combined the truck scheduling problem with the dock door assignment problem and developed a generic model for truck scheduling and dock door assignment problem as an MIP model (Shakeri et al, 2008). Wei, et al have proposed the ideal rule of dispatching a truck using the parameters throughput and system supported by RFID technology. The study has found that the best strategy is the Shortest Remaining Production Time rule (Wei et al, 2009).

Boysen has proposed a truck scheduling model in the context of the food industry. The food items which already came in the inbound door are loaded immediately to the outbound truck and then ship to the customer since there is a strict cooling requirement. The objective of this model is to minimize the flow time, processing time and tardiness of outbound trucks (Boysen,2010).

Discussion

Although the articles referred here have discussed the types of cross-docks and shapes of cross-docks separately, the cross-dock shapes that are more suitable for respective cross-dock types have not stated in the studies.

Therefore, with respect to the articles referred, table 1 is suggested which shows the cross-dock shapes and numbers of doors that will be more suitable for each cross-dock type identified above such that the throughput of the warehouse is maximized. These shapes have been suggested based on activities performed at the cross-dock facility and the flow of cargo in each cross-dock type in the cross-dock facility.

Table 1 Sugested Cross-Dock shapes and No of Doors for respective cross-dock types

Cross-dock Type	Suggested Physical Characteristics	
	Cross-Dock Shape	No of doors preferred
Cross-dock Type based on the place of consolidation		
Pre allocated supplier consolidation	I, L shapes	Less than 100 doors
Pre allocated Cross-docking Operator consolidation	I, L, T shapes	100-200 doors
Post allocated cross-docking operator consolidation	I, T, H, E, shapes	100-200 doors

Cross-dock Type based on the state of the supply chain		
Manufacturing Cross-docking	I, T, H shapes	100-200 doors
Distributor Cross-docking	H, E shapes	More than 200 doors
Transporter Cross-docking	I, H, E, X shapes	More than 200 doors
Retailer Cross-docking	L, U, H, E, X shapes	More than 200 doors
Opportunistic Cross-docking	I, L shapes	Less than 100 doors

Other than the physical characteristics considered above, a better relationship developed with effective communication with the stakeholders; suppliers, customers, warehouse workers, transporters etc. is essential for implementing an effective and efficient cross-docking system in the warehouse.

Conclusion

In the paper benefits of implementing a cross-docking system is identified as well as the complexities of implementing a cross-docking system. Also, the paper has highlighted some important characteristics of an ideal cross-docking system. The study has discussed some of the important factors that are necessary to consider when implementing cross-docking system in a warehouse; cross-dock types for deciding an efficient cross-dock system, shapes of cross-docks used in the industry and their effectiveness, models that has been developed for material handling problems within the warehouse and truck scheduling problems developed by the authors with the objective of minimizing the transportation time, cost. A future research question would be to analyze the effectiveness of cross-dock shapes with respective to different cross-dock types.

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