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Study on Distribution Centre Based Supply Chains and Cross-Dock Simulations

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Abstract - Businesses are putting new strategies into place to satisfy the demands of their customers in terms of cost, schedule, and quality. One of these tactics is cross-docking, which is the practice of grouping items with various suppliers that are headed to the same location while requiring little to no processing or storage in between the loading and unloading of the cargo. This study aims to explore the advantages of having a cross-docking facility inside a supply chain. In this study, we use the open-source Java Simulation Library (JSL) to create discrete event simulation models. We are also working on adding cross-dock facility modelling to an object-oriented library used in supply chain simulations. The receiving, sorting, and load building processes are all included in the crossdock facility modelling. The operational performance of the cross-dock's internal operations is not required, thus thorough modelling of the cross-dock's resources—such as the quantity of employees and equipment—is not included in the modelling. However, as the focus is on how the cross-dock impacts supply chain performance, the flow, time delays, and inventory components are modelled. In order to determine the important aspects that significantly impact the performance of the two types of supply chains, simulation tests are carried out to evaluate the object-oriented library's performance and compare the performance of two multi-echelon inventory networks with and without crossdocking.

***Key Words*:** JSL, cross-dock facility, time delays, inventory, simulation.

1.INTRODUCTION

In order to increase productivity, the trucking industry invented cross-docking in the 1930s. In its most basic form, it is moving products straight from incoming to outgoing shipments at a logistics centre, negating the need to store the products. Because commodities "cross the docks," travelling from vehicles that arrive at a receiving dock to vehicles that take the items at a shipping dock, the method is known as cross-docking. Even though items usually don't stay at the facility for very long, cross-docking occasionally entails the temporary storage of commodities. Businesses carry a variety of items using many product distribution networks. Most of these networks have distribution centres that hold goods from various vendors and subsequently supply the shops with what they want. Cross-docking facilities are used by many large organizations, such as Walmart, which views cross-docking as one of the main factors contributing to its excellent customer service standards, in order to remove the storage activity and lower expenses related to it (Galbreth et al., 2008). Examining the advantages of having a cross-docking facility in a supply chain is the goal of this thesis. In order to compare the performance of a cross-docking facility with the performance of a distribution centre in a supply chain, this research will concentrate on the creation of discrete event simulation models. We'll evaluate the two systems' performance in various scenarios, such shifting demand. The simulation models will be created using the Java Simulation Library (JSL), and various performance indicators will be computed and examined using statistical analysis. Because cross-docking expedites delivery times, businesses that need to transport large quantities of items fast, especially if those commodities are perishable—frequently adopt the technique for supply chain management. Cross-docking is a common practice used by supermarkets to expeditiously transport goods from farms, factories and other suppliers to retail outlets via distribution centres. Truckloads of vegetables that are delivered by farmers are divided, rearranged, and mixed with items from other vendors to make truckloads of commodities that are sent out to other retailers. Cross-docking is a common practice at specialised docking locations close to important transit hubs, including airports. Usually fashioned like an I, these cross-docking facilities include outbound docks on one side and inbound docks on the other. This arrangement reduces the distance between receiving and shipping items at the facility while increasing the number of ports that trucks may use simultaneously.

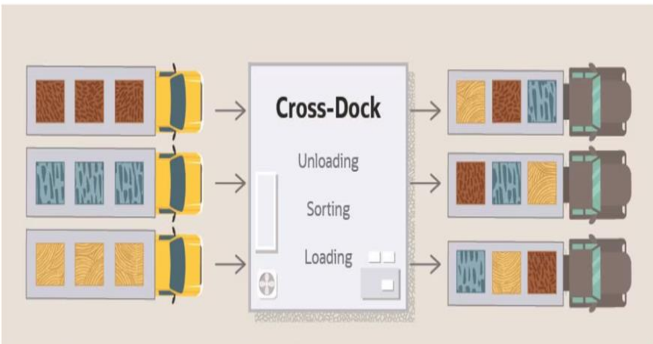

Fig.1.1. Cross-docking goods unloading, sorting and loading

The process of cross- is a logistics strategy designed to boost supply chain effectiveness and expedite the delivery of products. It entails, with little to no storage time in between, unloading cargo from trucks handling incoming shipments at a logistics centre and moving it to vehicles managing leaving shipments. Businesses use cross-docking to reorganise goods for effective delivery to retail locations, fulfilment centres, and clients. It also helps them combine products from many vendors and divide large shipments into smaller quantities. Close collaboration between a business's suppliers and freight carriers, as well as other supply chain participants, is necessary for cross-docking. Businesses may deliver goods more quickly, use less space in warehouses, improve inventory control, and save money on labour and transportation by making these efforts.

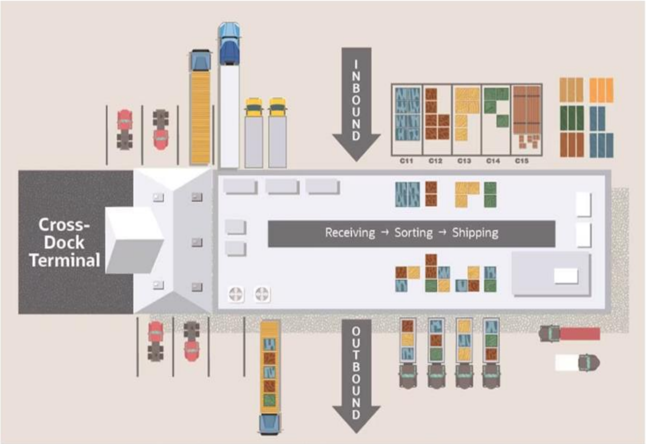

Fig.1.2. Complete cross docking process with inbound and outbound sections

The efficiency of a company's supply chain determines its competitiveness and success. As a result, companies are creating new plans to meet the needs of customers in terms of price, timeliness, and quality. Cross-docking is a strategy that involves combining products from different suppliers that are headed to the same location with little storage or handling in between cargo loading and unloading **(Belle et al., 2012).**

A number of characteristics separate different forms of cross-docking. The literature highlights the importance of the number of touches. One-touch cross-docking transfers items straight from an inbound to an outgoing truck. During multiple or two-touch crossdocking, items are unloaded and staged on the dock before loading into an outbound truck (Cross-docking trends study, 2008). Furthermore, the distinction may be created based on the customer's product allocation stage. Pre-distribution cross-docking involves the supplier assigning the customer to the goods and performing labelling and processing procedures. Post-distribution cross-docking involves assigning items to consumers and labelling them **(Yan & Tan, 2009).**

Under the correct circumstances, cross-docking of any kind can improve the performance of the supply chain. A cross-docking facility can do away with the need for both picking and storing, which lowers labour expenses, inventory holding costs, and material handling costs. Furthermore, by facilitating a quicker product flow, cross-docking reduces the lead time for product delivery **(Galbreth et al., 2008; Ertek, 2005).**

However, the introduction of cross-docking into a supply chain presents many decision-making challenges at the cross-dock and across the whole supply chain network. These three decision-making scenarios fall into one of three categories: tactical, operational, or strategic. For instance, according to **Buijs et al. (2014)**, the cross-dock and network's architecture is a strategic issue, while its planning, scheduling, and execution are tactical and operational issues. Numerous studies have been conducted to address the various issues that arise locally at the crossdock, and various approaches, including as simulation and optimisation, have been employed to resolve these issues.

One research examined the timing of many trucks and shop floor activity at a cross-dock. This study suggested a mixed integer linear programming model for scheduling truck arrivals, departures, and cross-dock-floor operations. The study aimed to reduce operational and shipping expenses **(Serrano et al., 2016)**.

Similarly, **Nassiefa et al. (2016)** employed mixed integer linear programming with Lagrangean relaxation to solve the door assignment issue in a cross-dock, aiming to decrease material handling costs.

2. METHODOLOGY

Research methodology is a collection of certain steps or methods utilized in the research process. Our primary goal was to create a simulation framework for supply chains based on cross-dock and distribution centers, thus we used a typical object-oriented modelling and analysis technique, which includes:

- Conceptualization
- Analysis
- Design
- Implementation and Testing

2.1 Conceptualization

The models needed to represent supply chains based on distribution centres and cross-docks have to be conceptualised initially. Creating a problem specification for each of the two systems, which may precisely specify the subject of the modelling, was part of this stage. It comprised outlining the components and functions of the two systems. After identifying the problem description, we began to consider the performance metrics and input parameters that would enable us to compare and contrast the two systems' differences and efficiency. The research proceeded to analyse the problem specification in order to determine the possible classes that would be required in order to represent the systems. The next section will provide details on this phase.

2.2 Analysis

We worked on determining the objects' primary classes in this stage. Every one of these items has unique characteristics, actions, and connections to other objects inside the system. One way to define an object's attribute is as a quality or feature that has to be kept and recalled. The objects' behaviors can be modeled with techniques that operate alone or in concert with other objects or techniques to carry out certain tasks. UML diagrams may be used to illustrate how the classes work together. As a result, in this study phase, we created simple

UML diagrams to show the key methods of each class, define the main areas of collaboration between the classes, and ascertain the fundamental characteristics of each object.

2.3 Design

We thoroughly examined the categories and their attributes throughout this step. Clear definitions of the methods and their signatures were provided, and the methods that were required to specify and depict the cooperation between the classes were used. Furthermore, several important modeling concerns were tackled during this stage to determine an appropriate method for modeling them using the established classes and connections. Following this stage, we had the simulation framework's conceptual foundation, which still needed to be converted into Java code. This was completed during the implementation phase, which is covered in the section that follows.

2.4 Implementation and Testing

The process of implementation was the most important in this study. We mapped system design to code to construct simulation frameworks. The code was written in Java and utilized in the Java Simulation Library. After creating the Java code, we built and verified test cases with text statements to ensure proper system flow and functionality.

We examined the phases several times during the research, particularly during the implementation phase. To represent certain circumstances, we needed to adjust throughout the design process. This document's modelling part will provide a comprehensive description of class modelling and attributes.

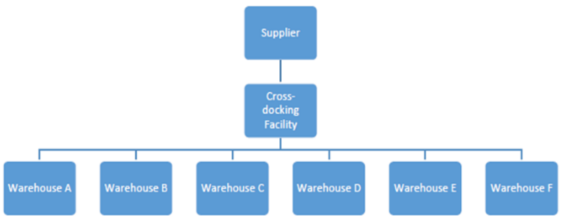

Fig.1 Cross-docking goods unloading, sorting and loading

Warehouse	A				B				C			
Item Type	1	2	3	4	1	2	3	4	1	2	3	4
Reorder Point	200	4	3	2	50	1	2	450	500	5	10	350
Reorder Quantity	180	7	6	5	131	2	3	329	462	8	27	405
Time between Demands (days)	35.18	1.93	1.23	0.75	19.1	0.44	0.5	61.7	69.5	2.19	5.18	44.9
Warehouse	D				E				F			
Item Type	1	2	3	4	1	2	3	4	1	2	3	4
Reorder Point	500	150	15	20	250	1200	1220	650	50	300	250	300
Reorder Quantity	458	126	29	101	336	399	483	377	156	150	300	322
Time between Demands (days)	69.95	24.7	6.39	14.12	38.9	111.9	134.7	82.1	19.9	33.9	40.1	40.2

Table 1: Parameters of the Cross-Dock Multi-Echelon Inventory System (Rossetti & Xiang, 2014)

2.5 Order Processing

Every warehouse experience demand, and its ability to meet that need is determined by the stock on hand. The entire order is backordered if there is insufficient stock on hand. It is the external supplier's responsibility to meet demand for a particular product and when an order is placed for a backorder or replenishment, the supplier crossdocking facility warehouses A, B, C, D, E, and F supply the warehouse. Figure 2 depicts this order flow between the various sites.

since of the high cost of transportation, shipments cannot be sent straight from supplier to warehouse since orders from a warehouse may not fill a full truckload. Consequently, the provider employs a single vehicle to deliver orders to several locations. This truck travels to the cross-dock, where goods headed for the same warehouse are sorted. The lead time, shown by F1 in Table 3, is the total of the lead times for manufacturing and transit between the cross dock and the supplier. Table 3 contains all references to distributions that come after.

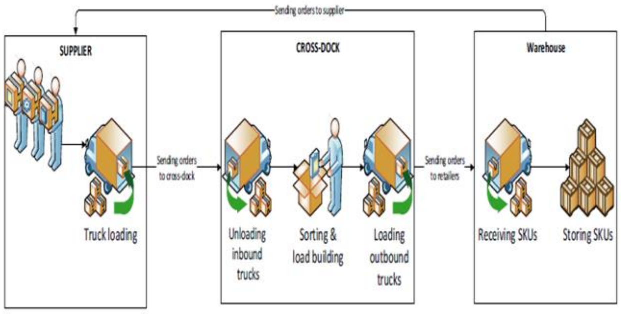

Fig.2 Conceptual System Description for CD-MEIN

2.6 Key modeling issues

Various significant modelling challenges will arise while modelling both systems. The most important points are summarized here.

- **Outbound trucks departure:** When a truck departs a cross-docking facility is a crucial decision that depends on several aspects such as the warehouse policies and the weight and volume limitations of full truckloads. This document is predicated on the idea that a vehicle departs the cross-docking facility upon reaching the truckload's lower weight or volume restriction. The entire truckload's weight restriction is between 5000 and 45000 pounds, and its volume limit is between 960 and 2000 feet. (Parsa and associates, 2017). If the vehicle waiting period exceeds 48 hours, we shall also presume that the vehicle departs from the facility. The car will take off in whatever scenario happens first.

- **Transportation resources:** Cars are used to move merchandise between the various locations. Every site may have its own transport system, or the various institutions may pool their cars. We believe that each supplier has cars that are in charge of delivering goods to DC or CD, and that each warehouse has its own vehicles that are in charge of delivering goods to it. Additionally, we consider that every facility has an infinite number of cars assigned to it.

- **Number of item types and warehouses:** A large number of warehouses and item kinds may make the simulation more difficult. Therefore, selecting the appropriate numbers is crucial to resolving this problem. The simulation for this study will begin using the numbers mentioned in the system description section. Next, we will calibrate the model to ascertain the appropriate values required to achieve a noteworthy flow of goods inside the systems.

- **Demand Filling:** There may not always be enough stock on hand to meet demand when it arises, and orders are placed with the external supplier or DC. There are several approaches to handling this situation. Since we're assuming partial fulfilment in this research, we'll use the stock that is currently on hand to fill a portion of the order and backorder the remaining portion.

3. MODELING

This chapter presents a conceptual model of cross-dock and distribution center-based supply chains, followed by a detailed discussion of the framework's elements, roles, qualities, and interactions. We will discuss significant modelling difficulties encountered during framework development.

3.1 Conceptual Modeling

We initially determined the fundamental components needed to construct the two supply chain systems in order to represent the cross-dock and distribution center-based supply chains. Demand fillers, demand senders, shipment receivers, locations, facilities, demand generators, shipment builders, and shipment carriers were identified as these fundamental components. There could be connections between any of these components and other components in the framework. The majority of these components were found to be either abstract classes or interfaces in the framework, which are then utilised to model more detailed classes. This section outlines the main components of the framework and emphasises their functions.

A series of actions take place in any supply chain that is based on a distribution centre or cross-dock in order to satisfy client requests. For instance, the following may be used to characterise the flow of events in a cross-dock based supply chain:

- A demand generator creates the need for a certain quantity of goods.
- The demand is received at a designated facility that serves as the demand generator's filler.
- The inventory of the facility is examined to ascertain whether or not demand can be directly met. Should sufficient inventory be available, the demand will be met right away. If not, the facility's filler—in this case, a cross-dock—will get a replenishment order, and the demand will be backordered. Since we assumed in our framework that a cross-dock does not have inventory held in it, the filler gets the replenishment order and delivers it straight to the external provider.
- The carrier loads and transports the shipment to the facility.

- The facility receives, unloads, and dispatches the consignment, fulfilling back-ordered requests.

In the next part, we will provide a detailed description of how to represent the framework objects and their flow of events.

3.2 Detailed Modeling

Based on the basic model features discussed in the previous part, we provide a more thorough illustration of the framework's evolution in this section. We explain how cross-dock and distribution center-based supply chains that are particular to each user may be modeled using this framework. Implementing interfaces and abstract classes makes this simple since they let users create custom supply chains by subclassing them and customizing the functions. The items in the supply chain systems, along with their functions, characteristics, and relationships with other objects, are covered in this section. To demonstrate how to utilise the framework to model a basic multi-echelon inventory system, which comprises of a warehouse, a distribution centre, and an external supplier, we outline the modelling process. For the sake of simplicity, we will assume that each site in the system only stocks one kind of item, and that the distribution centre and the warehouse have inventory policies with reorder point reorder amount (r, Q). When a replenishment request is made, the distribution centre feeds the warehouse, and the external supplier fills any orders that the distribution centre places.

Table 2: List of Classes

New Classes			Previous Classes
CrossDockFacility	DistributionCenter	Shipment	InventoryHoldingPoint
ExternalSupplier	FacilityAbstract	ShipmentBuilder	Demand
LocationAbstract	GroupDemandGenerator	ShipmentsCarrier	DemandGenerator
ReceivingDock	ShippingDock	Network	ItemType
WarehouseFacility	StorageFacilityAbstract		

This framework assumes an empty system (at time=0) with no flowing needs. Additionally, the initial inventory level is determined by adding the reorder amount and reorder point, and all carriers are present at the plant. The simulation framework includes thirteen classes and four interfaces, as well as two additional interfaces and four classes introduced by Rossetti et al. (2008). Table 2 displays all of these classes, whereas Table 3 displays their interfaces. This section is organised into subsections that provide detailed explanations for modelling a certain class.

Table 3: List of Interfaces

New Interfaces	Previous Interfaces
FacilityIfc	DemandFillerIfc
LoactionIfc	DemandReceiverIfc
ShipmentFormingRuleIfc	DemandSenderIfc
ReceiveShipmentsIfc	

4. CONCLUSION

In this study, we created and implemented supply chain framework-based object-oriented simulation components for generic cross-docks. This study's primary goal was to examine and pinpoint the components required to model a cross-dock multi-echelon inventory network in order to evaluate the advantages of having a cross-dock in a supply chain. In order to do this, we arranged the modelling components into a collection of objects that make up the simulation framework. These objects have characteristics, actions, and connections to one another. Additionally, we created a network class model, which makes it easier to simulate the modelling of any inventory network.

We examined the framework's components using actual cross-dock and distribution-center inventory networks to evaluate the framework's performance. The simulation framework's performance metrics show that it is operating as intended and that it can simulate authentic inventory networks with accurate outcomes.

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