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An investigation of production center-based distribution networks and cross-dock models using open-source (JSL) to generate discrete event simulation models

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Abstract - The purpose of this study is to examine 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 develop discrete event simulation models. We are also developing an object-oriented framework for supply chain modelling that will include cross-dock facility modelling. Receiving, sorting, and loading are all included in the crossdock facility models. Since cross-dock's internal activities do not need operational performance, the modelling does not fully account for the cross-dock's resources, including personnel and equipment counts. However, the flow, time delays, and inventory components are all simulated because the main emphasis is on how cross-docking impacts supply chain performance. Simulation tests are used to evaluate the performance of the object-oriented library and to compare the performance of two multi-echelon inventory networks with and without crossdocking, with the goal of identifying the key elements that have a significant impact on the performance of the two types of supply chains.

Key Words: JSL, analysis, design, modeling, simulation.

1.INTRODUCTION

A crossdocking facility's optimal crossdock size, forklift count, receiving door count, and door arrangement can all be determined using discrete event simulation (Yang et al., 2011). These are just a few examples of how modelling and simulation can be used to solve various issues inside a crossdocking facility. Similarly, a typical cross-dock with all of its aspects was modelled using the simulation technique, and this model was used to evaluate how a rise in demand affected the cross-dock's performance (Magableh & Rossetti, 2005). Furthermore, the impact of a dedicated staffing strategy vs a global staffing policy on the functioning of a post-distribution cross-docking facility was examined using two simulation models (Cox & Rossetti, 2017). To provide an overview of the many research conducted to address a particular crossdocking issue, literature reviews were conducted. For further information in this field, see (Belle et al., 2012) and (Buijs et al., 2014). A supply chain comprises a network of facilities and distribution choices that collaborate to produce and distribute a product to the end user (Rajgopal, 2019; Rossetti & Xiang, 2014). One of the most promising distribution strategies that may be applied to improve the overall performance of the supply chain is cross-docking. As was already indicated, earlier research has concentrated on finding solutions to various issues that arise within cross-docking facilities. Nevertheless, the significance of evaluating a cross-dock's performance and viability in the context of the whole supply chain received minimal attention.

Research indicated that removing the typical warehousing stage in a global manufacturing firm's technological consumer goods supply chain may improve service and save costs. Suh (2014) evaluated the viability of adopting a cross-docking approach, which involves unloading and sorting inbound cargo from suppliers and loading them directly onto available departing trucks at the dock. Suh (2014) optimised cross-dock performance by regulating input and output parameters using a combination of discrete-event and agent-based simulation models. The criteria that were entered were the wait times for stock keeping units (SKUs), distributor orders, trailer full fraction, and trailer wait times. The number of trailers utilised, the SKU throughput time, the fill grade of less than trailer load (LTL) trailers, and the percentage of LTL trailers departing the dock were the output metrics. For the simulation findings to accurately represent the real situation, several assumptions had to be made. For instance, it was anticipated that the patterns of supply and demand would not change. Twenty distinct SKUs and fifteen merchants were simulated, with a provider representing each SKU. There were 500 distinct simulation runs produced by varying the input parameter settings. The author was able to comprehend the impact of each input parameter's alteration on all of the output parameters thanks to these simulation findings. In addition, the author found five instances in which the values of the cross-docking performance indicator were optimised. In a particular scenario, every output parameter was optimised, resulting in the lowest possible number of trailers overall, the highest possible LTL fill grade, and the shortest SKU throughput time. Two simulation scenarios were run in order to examine the outcomes of this instance more closely and see how various adjustments affected the optimised performance metrics. Within their limits, the trailer full fraction and overall average wait durations in the first simulation varied by one or two days. Regression models were created for each performance indicator based on the simulation runs, and these models revealed that all of the output parameters—aside from LTL fill grade—showed normal distributions. Any Logic's simulation was utilised to evaluate the impact of a variance of ±10% in distributor demands on the output parameters in the second simulation. After 200 simulation runs, the cross-dock achieves near-optimal performance when demand falls under a specific range. The simulation findings and sensitivity analysis helped decision-makers understand how each input parameter affected the output parameters. Optimising cross-dock performance is crucial for replacing traditional warehouses and improving overall supply chain performance. This study's approach optimises and assesses cross-docking performance. Monte Carlo simulations and sensitivity analysis assist evaluate the impact of factors on facility performance. The distribution centre facility's performance metrics, however, were not presented in this research under the same guidelines and circumstances. Measuring the advantages of switching from the conventional warehousing step to cross-docking requires comparing the performance metrics of the two systems.

In this research, we demonstrate the creation and use of a discrete event simulation model to reflect the operation of a cross-docking facility in a supply chain. The models evaluate how demand variations and other characteristics affect crossdock performance. The system is modelled using the Java Simulation framework (JSL), an open-source framework for discrete event simulation in Java (Rossetti & Xiang, 2014). More information about the JSL is available in (Rossetti, 2008).

Cross-docking can be divided into two categories: pre-distribution and post-distribution.

- Pre-distribution cross-docking: Using this method, a supplier of products determines the ultimate consumer or location of each product before truckloads of goods are shipped to a cross-docking distribution centre. The products are sorted, unloaded, and loaded onto departing trucks at the cross-docking facility in accordance with the present procedures. This strategy reduces the amount of storage space required at the cross-docking facility and is usually used when manufacturers and retailers are aware of the amount of inventory required by each customer or store ahead of time.

- Post-distribution cross-docking: Post-distribution cross-docking establishes the ultimate destination of commodities after their arrival at the cross-docking facility. The products are loaded onto departing trucks after being stored at the facility until their final destination is decided. This allows suppliers more time to decide, in light of demand, where products should be transported in the end. Companies can transfer items in and out of storage and minimize operating expenses with the aid of efficient warehouse management.

- Drop shipping vs. Cross-Docking: Cross-docking and drop shipping are two distinct strategies for effectively transferring goods throughout the supply chain. A company strategy called drop shipping keeps sales and fulfilment apart. A product is sold by a retailer or an online retailer; the product is not stocked by them. Instead, another business, usually a manufacturer or distributor, stocks the product and ships it straight to the buyer. In contrast, cross-docking is a logistics facility approach that facilitates the efficient distribution of resources and commodities by moving them straight from inbound to outbound carriers. Cross-docking is a technique used by large retailers and e-commerce businesses to transfer goods from distribution centres to retail locations or straight to customers.

- Direct Shipment vs. Cross-Docking: Direct shipment and cross-docking are both methods for minimizing supply chain costs and speeding the delivery of goods. With direct shipping, suppliers send goods directly to consumers, bypassing the need for retail stores or distributors. Companies that sell products directly to customers, also known as direct-to-consumer (DTC) brands, often use direct shipping to deliver products without maintaining a physical retail presence. In contrast, cross-docking, which involves moving goods directly from inbound to outbound carriers at a distribution center, is used by many major retailers and other companies that need to get products to their final destinations quickly and efficiently.

There are several types of cross-docking, each one tailored to meet different needs. Continuous cross-docking focuses on shortening overall delivery lead times by continuously moving goods through a distribution facility. Consolidation and deconsolidation cross-docking involve combining or splitting shipments at the facility; these methods aim to minimize transportation costs, as well as ensure timely delivery of goods. A single company may use more than one type of cross-docking, depending on the needs of the business.

- Continuous Cross-Docking: With little to no storage time needed, continuous cross-docking entails a constant flow of goods via a cross-dock facility. Products are loaded straight onto departing containers that transport them to their destination after being unloaded from entering trucks or other containers. The objective is to expedite the flow of commodities through the supply chain. High levels of coordination and synchronization are necessary for this kind of cross-docking between carriers, suppliers, and the business running the cross-dock facility. Continuous cross-docking is especially helpful for high-volume, always-in-demand items like food.

- Consolidation Cross-Docking: At a cross-docking facility, cross-docking consolidation entails combining several smaller incoming shipments into a single, bigger outgoing load. Since shipping one huge cargo usually costs less than shipping several smaller loads, the main objective is frequently to minimize transportation expenses. Consolidation cross-docking, in contrast to continuous cross-docking, necessitates the effective storage of items at the location until the business has assembled a complete truckload for departure. Businesses may track and automate procedures like receiving and managing goods and liaising with supply chain partners with the use of a warehouse management system.

- Deconsolidation Cross-Docking: Deconsolidation cross-docking is the opposite of the consolidation method. A large incoming load is divided at the cross-docking facility into multiple smaller shipments for delivery to customers. For example, parcel carriers may move goods across the country in a single large shipment and then split the shipment into smaller loads for delivery to customers. Retail stores receive large shipments from suppliers at their distribution centers and then divide the shipments into smaller batches for delivery to individual stores.

1.2 Risks of Cross-Docking

Cross-docking has a number of benefits, but it also has certain hazards. Effective cross-docking facility setup and upkeep need a lot of preparation, money, and persistent work. Coordination with other businesses in a supply chain and strong supply and demand visibility are also necessary for cross-docking. Here are a few of the primary dangers to think about:

- **Initial investment:**

To develop and construct specialised cross-docking terminals that satisfy businesses' demands, extensive planning is needed. Companies frequently invest in warehouse automation technology, such as robotics and conveyer belts to help move items about the facility, as well as sensors and other tools to track their movement, because the aim is to transfer goods rapidly and effectively. Even though this technology has a high upfront cost, businesses frequently recover these costs through increased delivery times and supply chain efficiency.

- **Supply chain vulnerability:**

For enterprises, supply chain stability is essential. Because they store less product in warehouses, businesses may be more susceptible to unforeseen interruptions in the supply chain. Businesses may soon run out of products to offer to clients if there is a disruption in the supply chain. Utilising real-time inventory management technology, businesses can monitor their existing stock levels and make sure they have enough of essential items on hand.

- **Demand forecasting errors:**

Businesses can make mistakes in estimating the quantity of goods that their clients want and end up short because they haven't stored enough inventory. To guarantee that goods are acquired and made accessible when consumers need them, accurate demand forecasting is essential.

- **Coordinating carriers and supply chain partners:**

Close coordination between all supply chain participants is necessary for cross-docking. When products arrive, a firm needs to make sure that their suppliers can supply them when needed and that it has enough carrier capacity to transport the items out of the cross-docking facility as quickly as possible. ERP solutions that offer extensive supply chain management functionalities may assist businesses in anticipating demand and guaranteeing prompt fulfilment of consumer requirements.

2. METHODOLOGY

A set of specific actions or techniques used during the research process is known as research methodology. Our main objective was to develop a cross-dock and distribution centre supply chain simulation framework, thus we employed a standard object-oriented modelling and analytic approach.

2.1 Cross-dock Operations

A receiving door is designated for the purpose of unloading the items from an arriving truck. There are five inbound doors, and the FIFO rule determines which cars are assigned to which doors. Unloading begins as soon as a car is allocated to a door, and it takes distribution F2 time to complete. Following the truck's complete unloading, the workers begin classifying the goods according to where they are going. This operation has distribution F3. After a full load is created, it is either relocated to a staging area or put immediately onto an outbound truck to the appropriate warehouse. There are 5 outward doors that may be allocated to one truck at a time. The loading procedure takes the duration of distribution F5. Outbound trucks depart the cross-dock with a full load or after a maximum 48-hour delay. Assume enough personnel availability for each phase.

2.2 Distribution Center Based (DC-MEIN) Multi-Echelon Inventory Network

The sole distinction between the cross-dock network and the distribution centre network is the presence of a distribution centre rather than a cross-docking facility, as Figures 1 and 2 demonstrate. The distribution centre in this instance receives replenishment orders and backorders from the warehouses using a (r, Q) policy for every kind of item.

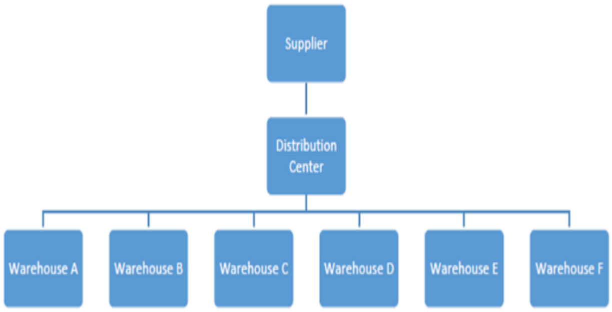

Fig.1 Distribution Center Based Multi-Echelon Inventory Network

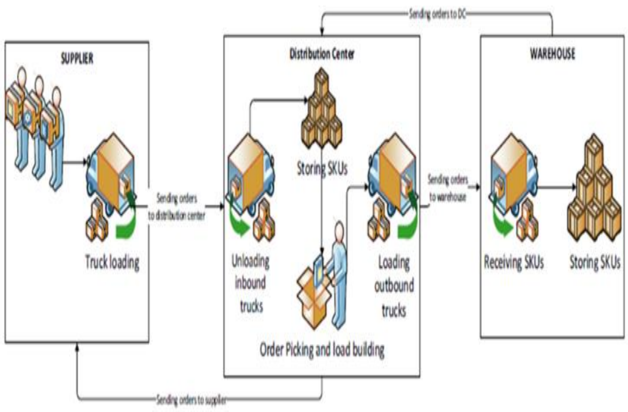

Fig.2 Conceptual System Description for System 2

Table 2: Activities Distribution Forms

Distribution Number	Activity Description	Distribution	Source
F1	Transportation time between the cross dock and the supplier	UNIF(2,4) days	(Xiang & Rossetti, 2014)
F2	Inbound vehicles unloading time	TRIA(5,25,40) minutes	(Magableh & Rossetti, 2005)
F3	Sorting time	TRIA(10,30,60) minutes	
F4	Load building time	TRIA(15,30,60) minutes	
F5	Outbound vehicle loading time at CD	TRIA(7,26,46) minutes	(Magableh & Rossetti, 2005)
F6	Picking and moving time	TRIA(10,20,30) minutes	
F7	Outbound vehicle loading time at DC	TRIA(7,26,46) minutes	
F8	Transportation time between warehouses and DC	UNIF(2,4) hours	(Rossetti & Xiang, 2014)
F9	Vehicle checking time	TRIA(5,10,15) minutes	
F10	Unloading time for inbound vehicle at DC	TRIA(5,25,40) minutes	
F11	Put away time (per order and each order has multiple items)	TRIA(30,45,60) minutes	

2.3 Distribution Center Operations

When a vehicle arrives at the facility, its information will be checked against the booking reference, and it will be assigned a spot for unloading. Assume this action takes place during distribution F9. The truck is unloaded at its designated site, with distribution F10. After unloading, a checking activity may occur, depending on the provider. To simplify, consider that not all suppliers require inspection. After unloading, products are kept in proper locations and transferred using material handling equipment. The put-away activity takes distribution time F11. Table 3 summarizes the probability of distributions for all actions in the two systems.

2.4 Input Parameters

The simulation model considers many input factors that impact the operation of cross-docking facilities and distribution centres. Examples for these parameters are:

- Time between demands and demand amount: In this study, "demand" refers to a request for a certain amount of a product to be deposited in a warehouse. Cross-docks are appropriate for items with strong and consistent demand, according to several research (Gue, 2007). Different values for the time between requests and demand quantities for each product are taken into consideration in order to further analyse this result. It is noted that as the time between demands rises, the level of demand drops since fewer demands enter the system in each length of time.

- Number of item types: Prior research on multi-echelon inventory systems did not focus much on how many item types are moved between locations and how it affects system performance. In order to determine whether the CD or DC method is preferable for a particular number of items under particular circumstances, this study looks at the matter.

- Load building policy: For distribution center-based supply chains, Rossetti and Xiang (2010) also looked at processing fulfilled demand based on various criteria. In a similar vein, this study will evaluate how these regulations affect supply chains that are CD- and DC-based to look at how the regulations affect the suggested design.

3. MODELING & SIMULATION

A conceptual model of supply chains based on cross-dock and distribution centres is presented in this chapter, which is followed by an in-depth analysis of the components, functions, attributes, and relationships within the framework. We will talk about important modelling challenges we ran with when building the framework.

3.1 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.

3.2 Modeling of a Facility using FacilityIfc and FacilityAbstract class

This part covers the modelling of the Storage Facility Abstract class, FacilityIfc class, and FacilityAbstract class. It also provides an example of a subclass of each class. As previously stated, we define a facility as a place that can both send and receive cargo from other places. Consequently, a FacilityIfc extends the ReceiveShipmentsIfc, which enables facilities to accept shipments from other locations or facilities, and the DemandSenderIfc, which enables classes that implement it to send demands to other places. Because it is a location as well, the FacilityAbstract class extends LocationAbstract and implements FacilityIfc, which sets it apart from a location. The class diagram shown in Figure 6 illustrates the LocationAbstract class structure.

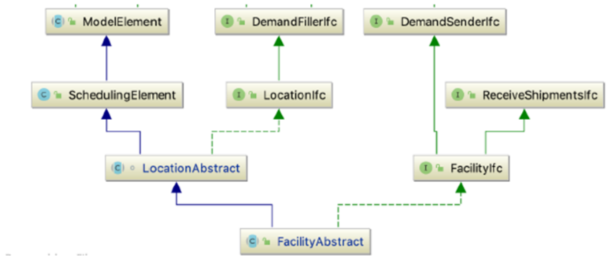

Fig. 3: Class Diagram for FacilityAbstract Class

The creation and connection of a distribution centre to the ES is demonstrated in Exhibit 2. Using the addItemType() function, we first build an instance of the DistributionCenter class and then add the item type to it. This function will help collect data for this particular item type by interacting with other protected methods in the model. Next, we use the addInventory() function, which accepts as inputs the item type, reorder point, reorder quantity, and starting level of inventory, to add the inventory for this item type. After a distribution centre is included in the model, it has to be connected to the outside vendor who will meet its needs. In this exhibit, we used the defaultaddCustomer() method with no shipment building rule, so we will always form shipments going to the DC regardless of the shipment weight or volume.

```
public static void Test(){
    Simulation e = new Simulation();

    Model m=e.getModel();

    ItemType  myItemType1=new ItemType(m,"Type 1");
    ExternalSupplier myExternalSupplier=new ExternalSupplier(m);
    RandomVariable myLeadTime1=new RandomVariable(m, new ConstantRV(5));
    myExternalSupplier.addLeadTime(myItemType1,myLeadTime1);

    DistributionCenter myDistributionCenter=new DistributionCenter(m);
    myDistributionCenter.addItemType(myItemType1);
    myDistributionCenter.addInventory(myItemType1,3,5,8);
    myExternalSupplier.addCustomer(myDistributionCenter);
}
```

Exhibit 2: Creating and Adding the Distribution-Center to the Model

WarehouseFacility class, which is a subclass of StorageFacilityAbstract, is another example. From this perspective, the primary distinction between a distribution centre and a warehouse is the kind of client that each serve. A warehouse is connected to demand generators that create demand, but a distribution centre may receive requests for demand from several warehouses. Demand generators will be covered in more detail in the article on group demand generators.

Exhibit 3 explains how to create a warehouse facility using the WarehouseFacility class. The warehouse, like the distribution centre, adds inventory using the addInventory() function previously explained. The warehouse was linked to the distribution centre via the addCustomerWithWeightShipmentBuildingRule() function. The distribution centre should create shipments to the warehouse based on the shipment building rule, which specifies the minimum and maximum weight for each shipment. This structure enables the establishment of several warehouses and their connectivity to the distribution centre.

```
public static void Test(){
    Simulation e = new Simulation();

    Model m=e.getModel();

    ItemType  myItemType1=new ItemType(m,"Type 1");
    ExternalSupplier myExternalSupplier=new ExternalSupplier(m);
    RandomVariable myLeadTime1=new RandomVariable(m, new ConstantRV(5));
    myExternalSupplier.addLeadTime(myItemType1,myLeadTime1);

    DistributionCenter myDistributionCenter=new DistributionCenter(m);
    myDistributionCenter.addItemType(myItemType1);
    myDistributionCenter.addInventory(myItemType1,3,5,8);
    myExternalSupplier.addCustomer(myDistributionCenter);

    WarehouseFacility myWarehouseA=new WarehouseFacility(m,"Warehouse A");
    myWarehouseA.addInventory(myItemType1,2,3,5);
myDistributionCenter.addCustomerWithWeightShipmentBuildingRule(myWarehouseA,25,40);
}
```

Exhibit 3: Creating and Adding the Warehouse to the Model

```
public static void Test(){
    Simulation e = new Simulation();

    Model m=e.getModel();
    ItemType  myItemType1=new ItemType(m,"Type 1");
    ExternalSupplier myExternalSupplier=new ExternalSupplier(m);
    RandomVariable myLeadTime1=new RandomVariable(m, new ConstantRV(5));
    myExternalSupplier.addLeadTime(myItemType1,myLeadTime1);

    CrossDockFacility myCrossDock=new CrossDockFacility(m);
    myCrossDock.addItemType(myItemType1);
    myExternalSupplier.addCustomer(myCrossDock);
}
```

Exhibit 4: Creation and Addition of Cross-Dock to the Model

The CrossDockFacility class is an example of a FacilityAbstract subclass. For the purposes of this study, it was believed that a cross-dock facility lacked previously held inventory that might meet requests from other facilities. Rather, it serves as a hub where goods bound for the same area are combined into a shipment in accordance with predetermined guidelines. Warehouses transmit demand requests to the external supplier, which then uses the cross-dock to transfer the goods back to the warehouses, as we previously described in the system description.

4. RESULTS & DISCUSSION

We first go over the performance metrics we employ in this part to evaluate the two systems' respective performances. After that, our main aim is to test the network class and the framework to ensure that every object in the inventory systems is operating as intended. The multi-echelon inventory systems for distribution centres and cross-docks are modelled using the data that was provided in the system definition section. We go into the factors that contribute to these results' reliability later in the validation subsection, which also confirms that the modelling is operating as planned.

4.1 Performance Measures

- Fill rate and aggregate fill rate: The percentage of customer demand that can be met by stock on hand without requiring a backorder is known as the fill rate. This rate, which can be assessed for both the facility and specific goods within it, is regarded as one of the most crucial metrics for customer service. The facility's fill rate, which is a demand-weighted fill rate, is referred to in this study as the aggregate fill rate. Stated differently, the total fill rate is the product of the fill rates for each type of item and the weight of demand for each type of item. We concentrate on the warehouse fill rates in each system in this analysis.

- Inventory on hand: The quantity of goods available for purchase or usage at a warehouse or distribution centre at any given moment is known as the inventory on hand. We assess each warehouse's inventory on hand in this study to see how it affects other performance metrics.

- Waiting time per item type in the shipment building area: The amount of time each item type waits to be transported to its final destination at the shipment building area of the cross-dock or distribution centre is known as the "waiting time per item type." We can ascertain how long the various item kinds are held in the shipment building area prior to being delivered to their final destination with the aid of this performance metric.

- Total inventory per item type in the shipment building area: The entire inventory per item type in the shipment building area of a cross-dock or distribution centre is waiting to be combined into a shipment and transported to its destination. This performance metric identifies which inventory system has the highest inventory per item type in the shipment building area.

- Total time to fill a demand in a warehouse: The whole period needed to satisfy a demand in a warehouse refers to the time it takes to fulfil a customer's request. If the warehouse has sufficient inventory on hand, this time is zero. This performance metric is affected by inventory levels in warehouses and distribution centres. Higher inventory levels lead to more frequent quick demand fulfilment.

- Total cost: Shifting from traditional storage to cross-docking aims to reduce total expenses. The simulation model will calculate the overall cost of the two systems, measured in $/year.

We used a complete factorial experimental design with 27 runs. Each simulation run lasted ten years, with a five-year warm-up phase. The inventory system's total cost was estimated using the components listed in the performance measurements section. The network class model allows for total cost estimation for any inventory system, regardless of parameters. Minitab software was used to create experimental design and graphs. Appendix B contains the whole experimental model. Figure 4 shows the impact of each element on the overall cost of DC-MEIN. This chart demonstrates how the threshold time and the interval between demands have a big impact on DC-MEIN's overall cost. For instance, the total cost falls as the threshold time rises, which makes sense because raising the threshold time results in fewer shipments, which lowers both the total cost and the shipping cost. Nevertheless, the overall cost of the DC-MEIN rises as the interval between demands is shorter, which means a higher demand rate. This shift in the overall cost is also anticipated given the rise in the number of orders placed, which drives up the cost of ordering as well as other expenses. Figure 4 further demonstrates that variations in lead times have little effect on overall costs, which may be attributed to a variety of factors. One explanation for this is the scarcity of instances. We looked at how these elements interacted in order to learn more about how these factors affected DC-MEIN's overall cost. There is no discernible interaction between the three components, as the interaction graphs in Figure 5 demonstrate.

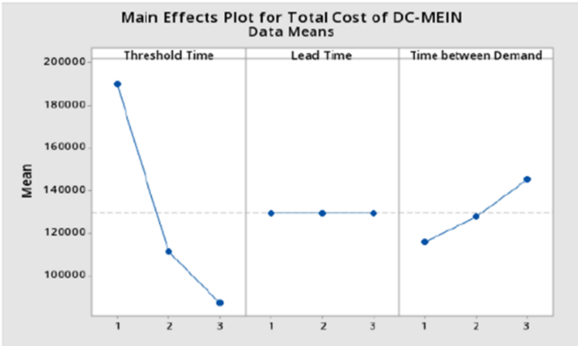

Fig 4: Main Effects of Plot for Total Cost of DC-MEIN

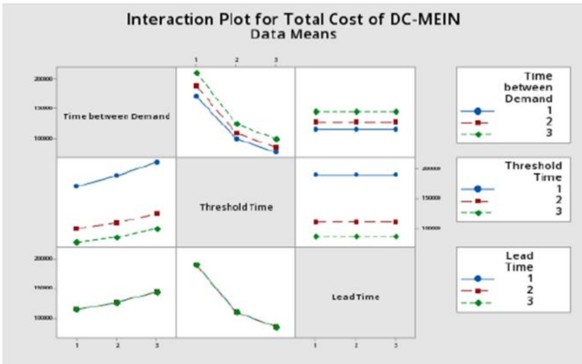

Fig 5: Interaction Plots for Total Cost of DC-MEIN

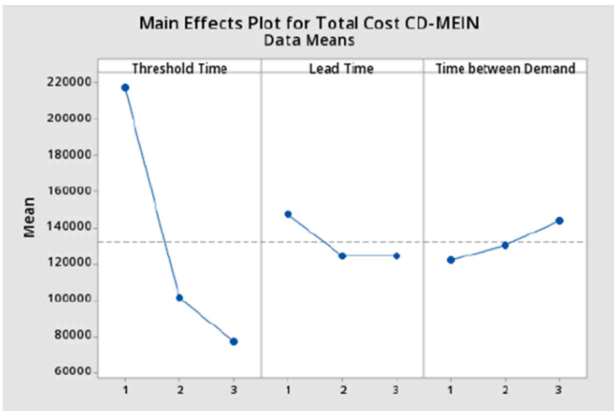

Fig 6: Main Effects on Plot for Total Cost of CD-MEIN

This scenario allowed us to confirm that our model is responding to fluctuations as intended and to see that a significant portion of the overall cost of the two systems may be reduced by raising the timetable.

4. CONCLUSION

We developed and implemented object-oriented simulation components for generic cross-docks based on the supply chain architecture in this study. The main objective of this research was to identify and analyse the elements needed to construct a cross-dock multi-echelon inventory network and assess the benefits of having a cross-dock in a supply chain. We accomplished this by organising the modelling elements into a group of objects that comprise the simulation framework. These things are related to each other and have traits and functions. We have developed a network class model that facilitates the modelling simulation of any inventory network. In order to assess the framework's performance, we looked at its component parts using real cross-dock and distribution-center inventory networks. The performance measurements of the simulation framework demonstrate that it is functioning as planned and that it can accurately model real inventory networks.

REFERENCES

1. Belle, J., Valckenaers, P., & Cattrysse, D. (2012). Cross-docking: State of the art. *Omega*, 827- 846.
2. Buijs, P., Vis, I., & Carlo, H. (2014). Synchronization in cross-docking networks: A research classification and framework. *European Journal of Operational Research*, 593-608.
3. Cox, D., & Rossetti, M. (2017). Simulation modeling of alternative staffing and task prioritization in manual post-distribution cross docking facilities. *Winter Simualtion Conference.*
4. Ertek, G. (2005). A Tutorial On Crossdocking. *3rd International Logistics & Supply Chain Congress.*
5. Galbreth, M., Hill, J., & Handley, S. (2008). An investigation of the value of cross docking for supply chain management. *Journal of Business logistics*, 225-240.
6. Gue, K. (2007). *Warehouses Without Inventory.* Springer.
7. Magableh, G., & Rossetti, M. (2005). Modeling and analysis of a generic cross-docking facility. *Winter Simulation Conference*, (pp. 1613-1620).
8. Nassiefa, W., Contrerasa, I., & As'ad, R. (2016). A mixed-integer programming formulation and Lagrangean relaxation for the cross-dock doorassignment problem. *International Journal of Production Research*, 494–508.
9. Parsa, P., Rossetti, M., Zhang, S., & Pohl, E. (2017). Quantifying the benefits of continuous replenishment program for partner evaluation. Int. J. Production Economics, 229-245.
10. Rajgopal, J. (2019). *Supply Chains: Definitions & Basic Concepts.*
11. Rossetti, M. (2008). JSL: An open-source object-oriented framework for discrete event simulation in Java. *International Journal of Simulation and Process Modeling*, 69-87.
12. Rossetti, M., & Xiang, Y. (2014). The effect of backlog and load-building processing in a multiechelon inventory netwrok. *ELSEVIER*, (pp. 54-66).
13. Rossetti, M., Miman, M., & Varghese, V. (2008). An object-oriented framework for simulating supply systems. *Journal of Simulation*, 1-14.
14. Serrano, C., Moral, J., Delorme, X., & Dolgui, A. (2016). Cross-docking Operation Scheduling: Truck Arrivals, Shop-Floor Activities and Truck departures.
15. Suh, E. S. (2014). Cross-docking assessment and optimization using multi-agent co-simulation: a case study. *Springer*, 115-133.
16. Xiang, Y., & Rossetti, M. (2014). The effect of backlog queue and load-building processing in a multi-echelon inventory network. *Simulation Modeling Practice and Theory*, 54-66.
17. Yan, H., & Tan, S.-l. (2009). Pre-distribution and post-distribution cross-docking operations. *ELSEVIER*, 843-859.
18. Yang, K. K., Balakrishnan, J., & Cheng, C. H. (2011). An analysis of factors affecting cross docking operations. *JOURNAL OF BUSINESS LOGISTICS*, 121-148.
19. F. Dexter, A. Macario, R. D. Traub, M. Hopwood, and D. A. Lubarsky, "An operating room scheduling strategy to maximize the use of operating room block time: computer simulation of patient scheduling and survey of patients' preferences for surgical waiting time," Anesthesia & Analgesia, vol. 89, no. 1, pp. 7–20, 1999.
20. D. Masursky, F. Dexter, C. E. O'Leary, C. Applegeet, and N. A. Nussmeier, "Long-term forecasting of anesthesia workload in operating rooms from changes in a hospital's local population can be inaccurate," Anesthesia & Analgesia, vol. 106, no. 4, pp. 1223–1231, 2008.
21. A. Aravazhi, "Hybrid machine learning models for forecasting surgical case volumes at a hospital," AI, vol. 2, no. 4, pp. 512–526, 2021.
22. S. Trivedi and N. Patel, "Optimizing or efficiency through surgical case forecasting with arima averaging," ACST, vol. 1, no. 1, pp. 7–17, 2021.
23. V. Tiwari, W. R. Furman, and W. S. Sandberg, "Predicting case volume from the accumulating elective operating room schedule facilitates staffing improvements," Anesthesiology, vol. 121, no. 1, pp. 171–183, 2014.
24. N. K. Ahmed, A. F. Atiya, N. E. Gayar, and H. El-Shishiny, "An empirical comparison of machine learning models for time series forecasting," Econometric reviews, vol. 29, no. 5-6, pp. 594–621, 2010.
25. Z. Cui, W. Chen, and Y. Chen, "Multi-scale convolutional neural networks for time series classification," arXiv preprint arXiv:1603.06995, 2016.
26. S. Kaushik, A. Choudhury, P. K. Sheron, N. Dasgupta, S. Natarajan, L. A. Pickett, and V. Dutt, "Ai in healthcare: time-series forecasting using statistical, neural, and ensemble architectures," Frontiers in big data, vol. 3, p. 4, 2020.
27. Z. C. Lipton, D. C. Kale, C. Elkan, and R. Wetzel, "Learning to diagnose with lstm recurrent neural networks," arXiv preprint arXiv:1511.03677, 2015.
28. T. Pham, T. Tran, D. Phung, and S. Venkatesh, "Deepcare: A deep dynamic memory model for predictive medicine," in Pacific-Asia conference on knowledge discovery and data mining. Springer, 2016, pp. 30–41.
29. I. R. Widiasari, L. E. Nugroho et al., "Deep learning multilayer perceptron (mlp) for flood prediction model using wireless sensor network based hydrology time series data mining," in 2017 International Conference on Innovative and Creative Information Technology (ICITech). IEEE, 2017, pp. 1–5.
30. B. Zhao, H. Lu, S. Chen, J. Liu, and D. Wu, "Convolutional neural networks for time series classification," Journal of Systems Engineering and Electronics, vol. 28, no. 1, pp. 162–169, 2017.