International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2015): 78.96 | Impact Factor (2015): 6.391

Simulation Modeling and Analysis of Cross Dock Implementation in Distribution Network

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Abstract: ***This paper presents the salient details of the development and analysis of a simulation model of a cross dock distribution network. The network consists of three suppliers and five customers. The number of cross docking facilities (CDF) is varied to analyze the performance of CDF under a dynamic environment. Any of the five customers can place order to any of the three suppliers. The decision factors considered are number of trucks, dispatch rules, truck size and order interval. The objective is to reduce lead time for customer order fulfilment and to find the minimum number of vehicles required to maximize service level and truck utilization. Hence, the performance measures considered are average lead time to deliver the products, service level, average truck utilization and total demand met. A simulation model is developed using ARENA software. Multiple comparisons are made within and between the decision factors and the optimum combination are determined.***

Keywords: Distribution, Cross dock, Simulation, Customer, Supplier

1. Introduction

Cross-docking is a logistics concept which integrates intermediate nodes into a transportation network. Within a cross-docking terminal, incoming shipments delivered by inbound trucks are collected, sorted by destination, and moved across the terminal to be directly loaded onto outbound trucks. These outgoing trucks immediately head to their next destinations in the distribution process. In contrast to a traditional warehouse, the storage of goods is reduced to the greatest extent possible, so that typically, all shipments leave the terminal within 24 hours. The primary purpose of a cross-dock is to enable a consolidation of many smaller shipments between multiple shippers and recipients so that only full truckloads (FTL) are transported (Apte and Viswanathan, 2000). In this way, economic transportation is realized and the hub-and-spoke distribution networks replacing traditional point-to-point deliveries are made possible. The review of the literature reveals that cross-docking problems have been addressed by many researchers, but with deterministic model and with many assumptions. Also, a limited number of studies have been done by considering the two problems together namely, scheduling and dock door assignment problem or scheduling with product allocation problem. Also, a lesser number of works is reported in the literature on considering multiple product types and different due dates.

This paper presents the salient details of the development and analysis of a simulation model of a cross dock distribution network consisting of three suppliers and five customers. In a CDF, products are consolidated according to the final customers. Products are dispatched to the final destination based on the due date. The decision factors considered are number of trucks, dispatch rules, truck size and order interval. The objective is to reduce lead time for customer order fulfilment and to find a minimum number of vehicles required to maximize service level and truck utilization. Hence, the performance measures considered are average lead time to deliver the products, service level, average truck utilization and total demand met. A simulation model is developed using the simulation software ARENA. Multiple comparisons are made within and between the decision factors and the optimum combination are determined. The rest of the paper is organized as follows: Section 2 provides a review of the literature review. Section 3 deals with the problem description. Section 4 deals with Developed simulation models, Section 5 deals with results and analysis. Section 6 provides conclusions.

2. Literature Review

Cross-docking has been known as the strategy of logistic in which the products from several suppliers can be consolidated become a single shipment. Maglabeh et al. (2005) developed a simulation model of a generic cross-docking facility to examine the operational risks associated with individual CDFs within a company's distribution network under a dynamic environment. The model is generic and can easily be expanded to model other cross-docking facilities. Agustina et al. (2010) modeled a mixed-integer program with the objective to optimize the cross dock warehouse operations so that the products can be delivered just in time also lowering the total cost of distribution. Derbes et al. (2009) developed a stochastic discrete-event simulation model for the problem where several scenarios are studied aiming at the most important factors that must be investigated in a cross-docking problem. Boysen et al (2010) introduces a base model for scheduling trucks at cross docking terminals which might be employed to solve more complex real-world truck scheduling problems. Yang et al. (2010) developed a discrete-event simulation model to determine the optimum level of the factors which influence the CDF such as minimizing the mean handling time per pallet.

3. Problem Description

In this study, there are three warehouses, five customer destinations and one CDF. Each warehouse has a different type of products. Any of the five customers can place multiple orders in any of the three warehouses. Once the customers place their specific orders (type and quantity), this information is shared among suppliers. Their demand will be met by the suppliers without any production delay. Trucks will be requested from the respective suppliers when the order is ready. At the CDFs, trucks unload their shipments and become available for other requests, and the shipments are consolidated in CDF. The orders are finally shipped to the final destination according to the priority rule which is earliest due date.

Activities that take place in warehouses are receiving orders from any of the customers, assigning attributes such as order size, order due date, order destination, order release time, packing, requesting the truck and transporting the shipments to CDF. Activities in CDF are unloading the shipment, moving the goods to shipping door, consolidation of goods according to the final destination, loading the goods, requesting the truck to final destination. It is challenging to route the multiple product types from the warehouse to destinations with minimum storage-inventory between supply chains and to consolidate goods according to the requirement of final destination in the Cross-Dock facility. Minimum number of vehicles and the vehicle size are required to meet the required service level.

Simulation models have to be developed based on the routing sequence considered in our model. The objective is to minimize work-in-process in CDF, to optimize truck utilization, to maximize service level and to minimize average waiting time in CDF. The assumptions made in the present study are as follows:

- The inventory at the warehouse and the resource capacity in CDF such as worker, trailer, etc are considered infinite.
- Loading and unloading time of shipment are negligible.
- Two truck types, one with 265 unit capacity (maximum possible batch size from any warehouse) and another with 500 unit capacity (Possible to carry all orders placed by the customers at a time).
- Truck transfer velocity is 80 km/hr.

4. Development of the Simulation Model

The decision factors, factor levels considered in our model are described in Table 2. Order generation attributes are shown in Table 1. Distances between every station are known.

Table 1: Customer Order Size and Due Date

Product type	Order size	Due date (hr)
Soap (from warehouse 1)	TRIA(11,21,33)	TRIA(85,95,110)
Shampoo (from warehouse 2)	TRIA(10,40,53)	TRIA(85,95,110)
Paste (from warehouse 3)	TRIA(5,10,20)	TRIA(85,95,110)

Table 2: Decision Factors and Levels

Decision factors	Level	Level description
Truck unit capacity	3	2 truck(1-receiving,1-shipping), 3 truck(1-receiving,2-shipping), 4 truck(2-receiving,2-shipping)
Truck size	2	265 units (each unit 218 x75 x26 cm Or 112700 cm3), 500 units (212550 cm3)
Order interval	2	Order arrives every 2 hours, Order arrives every 5 hours
Routing sequence	2	Sequence 1 – (Each time only one product type from one warehouse will be collected), Sequence 2 – (pick-up items from all warehouse and unloads in CDF)

This simulation study considers a distribution network which involves three warehouses, five customer destinations and one CDF. Each warehouse has a different type of product. Any of the five customers can place multiple orders in any of the three warehouses. Order generation logic modeled using Arena. The activities in CDF are modeled as shown in Figure 1. Trucks transported between warehouse and CDF is termed as Truck 1 and the trucks transported between CDF and customers are termed as Truck 2.

The replication length of the simulation is set at one month or 30 days (24 hours a day). The number of replications is 20 and the first 2 days are considered as warm-up period.

5. Results and Analysis

The number of experiments conducted using the model is 24 (3 truck unit capacity x 2 truck size x 2 order interval x 2 routing sequence).

Out of these 24 experiments, the experiments which result in better performance measure values are listed in Table 3

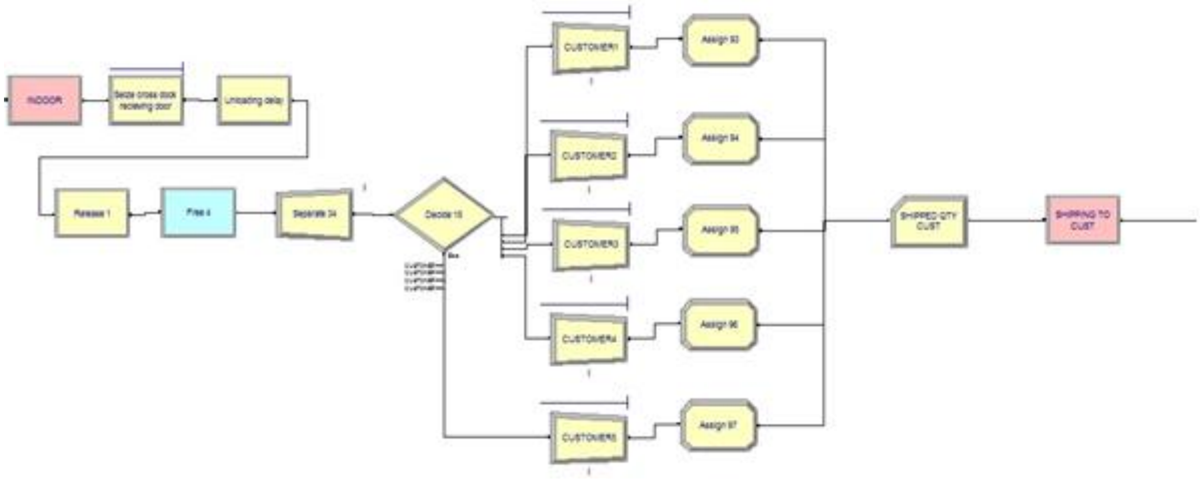

Figure 1: Simulation of a Cross Dock facility

Table 3: Simulation Results

Exp	Factors					Performance measures				
	Number of CDF	Dispatch rule	Truck size	Truck unit capacity		Truck Utilization		Service level	Lead time (hr)	Demand met
				Truck 1	Truck 2	Truck 1	Truck 2			
A	1	FIFO	265	1	1	1.00	0.86	31.01 %	44.9	40.19 %
B	1	EDD	265	1	1	1.00	0.83	33.65 %	45.66	40.27 %
C	1	FIFO	265	2	1	0.99	1.00	32.34 %	45.65	46.47 %
D	1	EDD	265	2	1	0.99	1.00	32.44 %	45.77	47.91 %
E	1	FIFO	265	2	2	0.99	0.97	85.70 %	19.22	95.74 %
F	1	EDD	265	2	2	0.99	0.95	84.86 %	24.68	94.00 %
G	2	FIFO	500	1	2	0.66	1.00	44.20 %	66	54.33 %
H	2	FIFO	500	2	2	0.43	1.00	95.50 %	7.1	96.17 %
I	2	EDD	500	2	2	0.43	1.00	95.53 %	7.44	96.23 %

Table 4: Score Based Multiple Comparisons

EXP	**Truck unit capacity (<=3) 0.2**	**Average Truck Utilization (>=85%) 0.2**	**Service level (%) (>=80%) 0.35**	**Average Leadtime (hrs) (<=20) 0.15**	**Order delivered (> 60,000) 0.1**	**TOTAL SCORE (1.0)**
A	0.2	0.2				0.4
B	0.2	0.2				0.4
C	0.2	0.2				0.2
D	0.2	0.2				0.4
E		0.2	0.35	0.15	0.1	0.8
F		0.2	0.35		0.1	0.65
G	0.2					0.2
H			0.35	0.15	0.1	0.6
I			0.35	0.15	0.1	0.6

5.1 Analysis

Simulation experiments are conducted with different factor levels. Figures 2 - 5 show the results obtained. When comparing among experiments, average truck utilization, lead time and service level are found to be favorable in experiment E which follows routing sequence 1 and truck unit capacity of 4 (one truck between warehouse and CDF, and two trucks between CDF and customer destinations) and dispatch rule is First In First Out (FIFO). Experiment F is similar to experiment E but the dispatch rule is earlier due date (EDD). In this case average truck utilization has reduced and lead time has increased which is unfavorable. Experiment I has the higher service level of 95.53%, lead time is also very less of 7.44 hrs but truck utilization is very less of 71.5%.

From Figure 2, it is clear that the lead time is found to be less in the case of selecting routing sequence 2 From figure 3, the mean service level is maximized in the case of routing sequence 2, larger truck size and truck unit capacity of 3. Also, it is suitable in case of order interval of five hours. From Figure 5, the mean truck utilization is maximized in the case of routing sequence 1, order interval of 2 hours, smaller truck size and when truck unit capacity is 4.

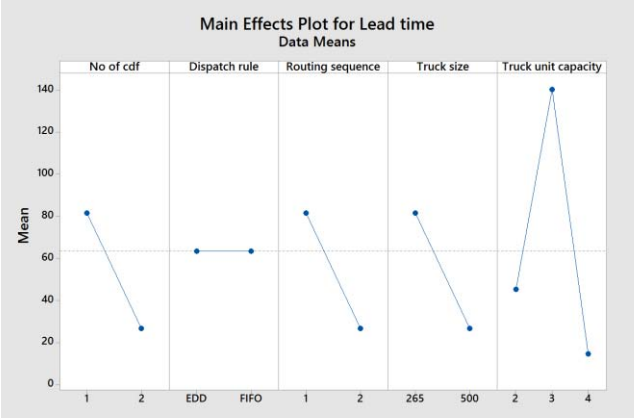

Figure 2: Mean lead time

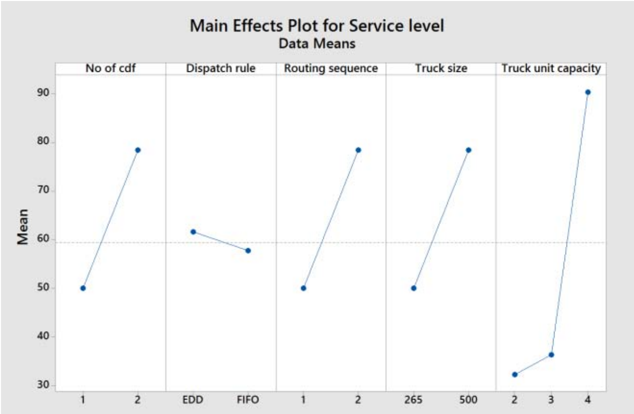

Figure 3: Mean service level

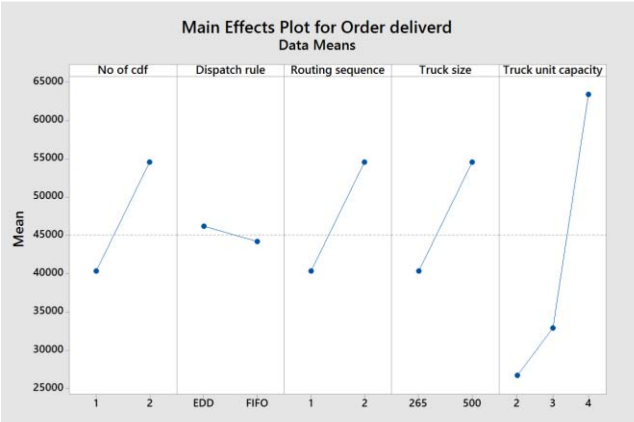

Figure 4: Total demand met

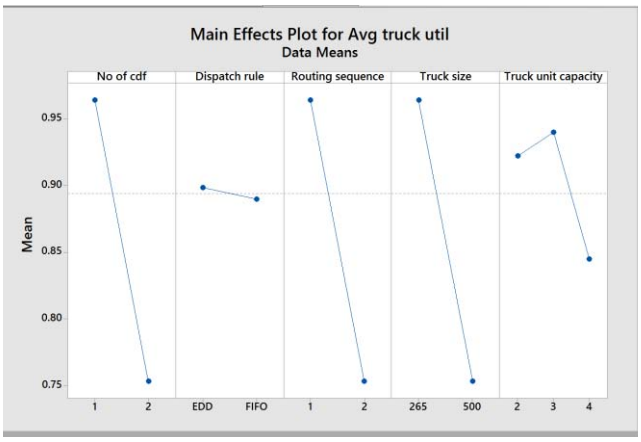

Figure 5: Average truck utilization

6. Conclusion and Future Work

The proposed simulation model allows analyzing different scenarios. Multiple comparisons are made between and among the factors by varying the levels of the factors. This model also helps to reveal the importance of model parameters such as the number of trucks assigned, truck sizes. Based on the scores assigned, experiment E has more favorable performance measures with total score of 0.8.

The model can be extended by integrating the CDF internal functions with the distribution network. More assumptions can be relaxed making the model more realistic. Detailed analysis can be done by involving more factors, factor levels and performance measures.

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