An Approach for Assessing Savings from the Restructuring of the Cross-Docking Process

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Abstract: The growing complexity of operations and logistics has pushed companies, especially large ones, to enhance their efficiency and performance evaluation, ensuring streamlined processes and cost-effective management. This study explores the optimization of internal distribution processes within companies by implementing a cross-docking (CD) system to enhance efficiency and speed. The CD is a distribution method for shipping materials to an intermediate cross-dock facility before reaching their final warehouse destination. This research specifically examines an alternative cross-docking approach to address inefficiencies in a company based in England. Materials undergo a double inspection, initially at the point of intermediate receiving and again at the final destination, leading to increased lead times and operational inefficiencies. By eliminating the initial, redundant inspection, and keeping that information in the system, the process can be streamlined, potentially reducing lead times and enhancing overall efficiency. Simulations of the current and proposed processes were conducted to evaluate the impact of these changes. The "to be" approach serves as an assessment of the savings resulting from the restructuring of the cross-docking process. The results indicate that reducing the time allocated for quality checks from 72% to 68% saves 47 minutes. This time savings allows for the reassignment of workers to other logistical tasks, improving operational flexibility, or it can lead to the reduction of one worker. As a result, workload distribution is optimized, enhancing lead times, efficiency, and cost-effectiveness.

Keywords: Simulation; Cross-docking; Logistics; Warehouse management; Supply chain management.

1. Introduction

In today's competitive landscape, companies must adopt fast and cost-effective strategies. Efficient distribution processes, such as cross-docking (CD), play a crucial role in warehouse management (Shams-Shemirani et al., 2024). Warehouse management includes receiving, inspection, re-package, put-away, storage, order picking, sorting, packing and shipping (Sinha & Muralidhar 2024). (Shams-Shemirani et al. 2024) claimed that crossdocking can reduce warehousing costs by over 30%.

Cross-docking is an efficient way to organize the transhipment of goods to save time, inventory and costs (Shams-Shemirani et al. 2024), (Kravchuk & Kravchuk, 2024), (Suh 2015). According to the article by (Kravchuk & Kravchuk 2024) and (Shams-Shemirani et al., 2024), The steps are multiple, from receiving the material to unloading the trucks, sorting according to the destination, reloading another truck, and delivering the products to the delivery destination. Figure 1 represents the shipment of goods in the CD process. In this process, in Figure 1, the supplier delivers materials to the receiving warehouse, where they are temporarily stored in the dock area. From there, these materials undergo the CD process before being shipped a second time to the destination warehouse.

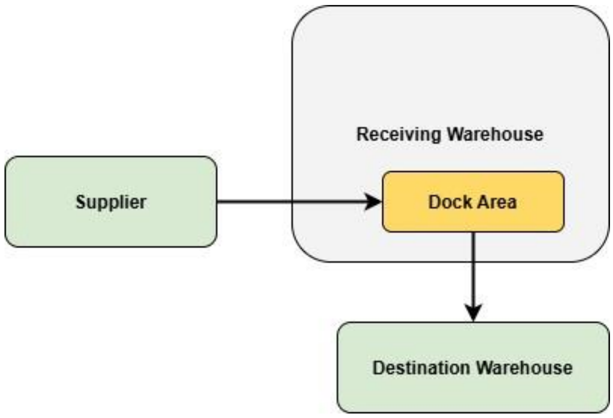

Figure 1: Material's cross-docking.

The performance of CD has impacts on the time, handling costs and distribution costs (Shams-Shemirani et al. 2024). There are various ways to enhance productivity and minimize different types of waste, such as overproduction, inventory, defects, motion, over-processing, waiting, and transportation, using a lean approach to thinking (Sinha & Muralidhar 2024).

CD aims to minimize stock levels, lead times, and truck travel while maintaining a high service level (Y Liu 2009). For this reason, coordination needs to be taken into account to eliminate inefficiencies and adopt lean logistics.

While previous studies (Y Liu 2009; Suh 2015; Torbali & Alpan 2023; Kravchuk & Kravchuk 2024; Shams-Shemirani et al. 2024)have concentrated on optimizing specific parts of the cross-docking process, our study aims to evaluate some potential different activities of the cross-docking process for lead time minimisation, over the operator's minimization.

Accordingly, the research questions of this study are:

1) How can the CD process be accelerated?
2) How can operational activities be streamlined to eliminate non-value-added tasks and enhance overall productivity?

The first research question focuses on how to expedite the CD activity, while the second highlights that the time saved could be utilized for value-added activities that may enhance productivity.

This research aims to simulate with a discrete event model the CD process of a company to analyse the performance of the process, reducing the waste as waiting, over-processing, motion and transport, as defined by (Sinha & Muralidhar 2024). Indeed, the quality check lacks efficiency as it can be streamlined and the time for the non-value-added activity can be used for others.

The paper is organized as follows: Section 1.1 reviews research on the lean approach to warehouse management and the simulations conducted to enhance efficiency through CD. Section 2.1 explains how CD is implemented within the company, while Section 2.2 discusses the data collected to input into the simulation created using AnyLogic. Section 3 presents the results, which compare the performance of various scenarios and parameters. Finally, Section 4 offers the conclusion and highlights the key implications of the findings.

1.1 **Background**

To optimize operations and generate added value without downtime, it is essential to identify and modify critical processes. One area where lean methodology is frequently applied is logistics. For instance, (Quiroz-Flores, Prada-Espinoza & Gutierrez-Villanueva 2022) focus on cross-docking (CD) as a key strategy for lean logistics. The study (Y. Liu 2009) assessed resource utilisation, as the used dock doors or sorting docks.

Simulation is a valuable tool for analyzing intralogistics material flows, as demonstrated in the study by (Arranz et al. 2023). Simulation is an efficient tool to evaluate the performance of different warehouse management strategies (Shams-Shemirani et al. 2024; Suh, 2015). There are three types of simulations: discrete event simulation, multi-agent simulation, and system dynamics simulation. System dynamics is particularly useful for simulating complex systems over time, especially for long-term and macro-level analyses. According to (Torbali & Alpan 2023)multi-agent-based simulation is utilised for scheduling decisions, while discrete event simulation is employed for operations at the cross-dock, and it is the most used in logistics. Moreover, (Liu 2010)noted that discrete event simulation can validate operations, test new ones, forecast potential risks, and optimise personnel planning, truck scheduling, and operational flow. With the help of simulations, it is possible to evaluate different scenarios with different interactions between the actors of the warehouse.

Several studies have explored different cross-docking models using simulation experiments (Y. Liu 2009). For example, Shams-Shemirani et al. (2024) optimised the number of entrance doors for trucks by simulating material flows using Business Process Modelling (BPM). Similarly, Kravchuk & Kravchuk (2024) utilized AnyLogic software to analyse how inbound and outbound truck time windows fluctuate based on input data. In another study, Suh (2015) demonstrated that simulation optimises cross-docking to align shipped stock-keeping units (SKUs) with orders. Additionally, (Shi et al., 2013) found that simulation aids in determining the optimal number of cross-docking doors, forklifts, and conveyors based on various decision factors. The study by (Y Liu 2009) used a simulation for performance analysis of inbound doors and operator utilisation. The article by (Torbali & Alpan 2023) simulated a scheduling model in which the truck for inbound-outbound needs to be synchronized. (Buijs, Danhof & Wortmann 2016) evaluate different scenarios on the theme of assigning the truck to the inbound doors and the re-layout of the preparation cross-docks for just-in-time activities.

2. **Methodology**

2.1 **Process flow**

The proposed methodology was developed by first analyzing the process flow of cross-docking activities. Figure 2 presents a process flow diagram illustrating the handling and movement of Handling Units (HUs) within a logistics environment. The BPM in Figure 2 begins with the receipt of materials in the receiving warehouse. The materials then undergo the CD process to reach their destination warehouse. During this process, the materials in the receiving warehouse must undergo an inspection process, depending on the characteristics of the items. Some activities are done physically by the operator, some by the scanning process and the last one by the system. The methodology is structured into two main areas: the receiving area and the delivery area, each encompassing distinct procedural steps.

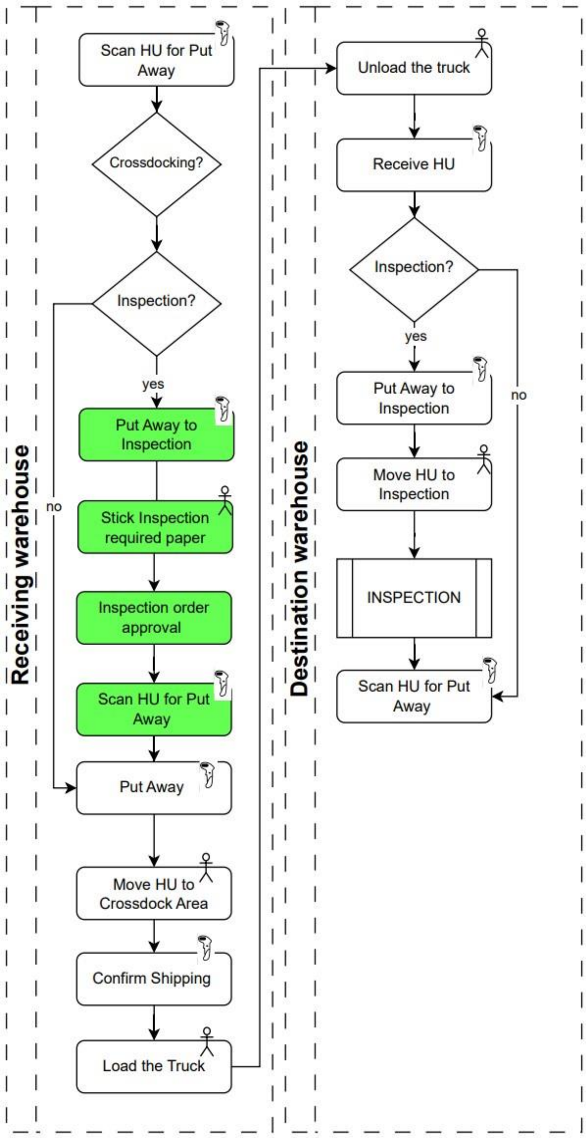

Figure 2: Cross-docking BPM flow.

The cross-docking process begins with the receipt of materials at the initial warehouse. Many HUs arrive simultaneously as the truck delivers a large quantity from the supplier, causing queues for processing. If an inspection is required, the HU is directed to the inspection process, where a quality inspection and approval of the parts are carried out, and the necessary documentation is attached. Following the inspection, the HU undergoes a secondary scanning process for put-away, ensuring adherence to standard storage procedures. If no inspection is necessary, the HU is immediately placed into storage.

The delivery process begins with unloading trucks and receiving the HUs. A decision determines whether an inspection is required. If so, the HU is transferred to the inspection area for evaluation. If no inspection is needed, the HU proceeds directly with the put-away process.

Analysing the process flow, it came out that the inspection in the receiving warehouse of the cross-docking was not necessary, as it should be done in the destination warehouse. So, the CD process can be done without these activities, the information should be taken into the system to not forget this characteristic. As a result, the lead time will be shorter than before, and operator usage will be reduced.

2.2 **Simulation modelling**

A simulation was done with Anylogic, a commercial software company. The development of the model is created to replicate the logistics cross-docking process. A part of the process was simulated as the quality activities were included to be improved in the receiving warehouse.

The duration of the activity was modelled according to the data of the company for the input parameters of the model, reported in Table 1. The authors in (Y Liu 2009) modelled the activity duration with a triangular distribution. For this reason, we did the same. The activities that lasted 0 seconds have been removed, but they are retained in Table 1 to clarify which ones have been deleted in the To-Be scenario, marked as N/A. These activities were highlighted in green in Figure 2.

Table 1: Time parameters

Activity	Parameters As-Is	Parameters To-Be	Units
Put away for inspection.	TRIA(1,2,3)	N/A	sec/HU
Stick inspection requires paper.	TRIA(1,2,3)	N/A	sec/HU
Inspection order approval.	TRIA(1,2,3)	N/A	sec/HU
Scan HU for putaway.	TRIA(1,2,3)	N/A	sec/HU
Move the item to the CD area	TRIA(25,40,50)	Unchanged	sec/HU
Confirm shipping	TRIA(1,2,3)	Unchanged	sec/HU
Load the truck	TRIA(10,20,30)	Unchanged	sec/HU

Table 2 presents additional data related to the company's operations. The data in Table 2, marked with a "-", indicates two different time slots: morning, from 1 to 12 hours, and afternoon, from 12 to 24 hours. The demand for cross-docking is influenced by the need for specific materials, while the other items do not require cross-docking and are instead stored in the high bay storage system. Some of these items need to undergo inspection, while others are sent directly to the destination warehouse. 12832 items need inspection out of 21189, so 60.5 % of the total items cross-docked need inspection. The items are scheduled in the morning until noon, and after that, until midnight, as transportation is available throughout the day. Since the duration of activities was measured in HU, the collected data needed to be in HU units. Therefore, we exported the packaging definitions for each item to determine the number of HUs.

There are five operators involved in various activities, working in three shifts each day to cover a total of 24 hours. They share responsibilities; for instance, the operators who put away materials during the inspection may also move HUs to the cross-docking area and load the truck. The HUs are loaded onto the truck simultaneously by operators for shipment to the destination warehouse. Each HU can contain different items; therefore, the percentage of inspected HUs in the simulation is assumed to remain at 60.5%.

The operator can approve the inspection in the receiving warehouse. A more thorough inspection will be conducted at the destination warehouse.

We developed two scenarios: the current state, which includes all activities, and the future state, which involves removing four quality activities.

Table 2: Collected data

Data	Value As-Is	Value To-Be	Units
Daily number of items received for CD.	21189	Unchanged	Items
Number of inspected products.	12832	Unchanged	Items
Scheduled, item (morning-afternoon)	11428-9761	Unchanged	Items
Scheduled, HU (morning-afternoon)	372-599	Unchanged	HU
Scheduled, inspected item (morning-afternoon)	5644-7188	Unchanged	Items
Scheduled, inspected HU (morning-afternoon)	263-514	Unchanged	HU
Scheduled, no inspected item (morning-afternoon)	5784-2573	Unchanged	Items
Scheduled, no inspected HU (morning-afternoon)	109-85	Unchanged	HU
Number of operators required to perform the inspection activities.	5	Unchanged	Operators
Number of operators required to perform the warehousing activities.	5	Unchanged	Operators
Working hours/day	24	Unchanged	Hours

The 'As-Is' version, illustrated in Figure 3, was created using AnyLogic. Figure 3 illustrates the activities conducted in the receiving warehouse, as shown in Figure 2. The CD process is more extensive, but the activities included are those that occur after the receiving step in the receiving warehouse and before the shipment to the destination warehouse, which is the final step of the CD process. Therefore, activities such as quality checks and the movement of materials to the CD area for loading onto the truck are illustrated in the flow chart in Figure 2 and simulated in Figure 3.

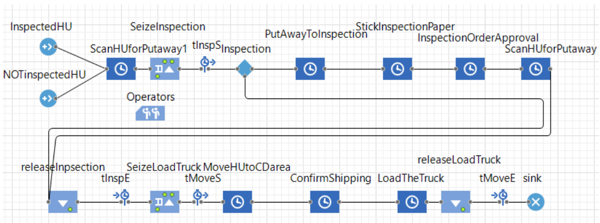

Figure 3: As-Is process.

The 'To-Be' version indicates an improvement over the previous one due to several modifications, as shown in Figure 4. The inspection phase in the receiving warehouse has been eliminated, as the company confirmed it is unnecessary. These deleted activities were highlighted in green in Figure 2. Moreover, the number of operators has been modified to evaluate an improvement scenario using a different parameter.

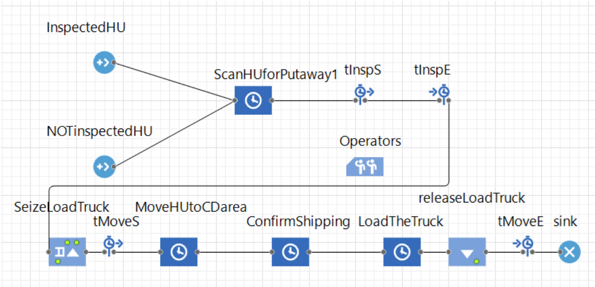

Figure 4: To-Be process.

3. Results

The simulation compares two different intralogistics scenarios, highlighting the impact of quality control activities on operator utilization. In the current scenario, operator utilization is 72%, whereas in the proposed scenario, it decreases to 68% due to a reduction in quality control tasks, as shown in Table 3. This shift enables a more efficient allocation of workers to other logistics activities. Workers can now handle tasks such as receiving materials, unloading trucks, sorting items by destination, reloading onto different trucks, and making deliveries.

The lower utilization in the proposed scenarios allowed for one less operator. With four operators instead of five, utilization increased from 68% to 79%, which is considered a good level, as shown in Table 3.

Table 3: Utilization of operators (%)

Scenarios	Utilization of operators As-Is	Utilization of operators To-Be	Units
5 operators	72	68	%
4 operators	86	79	%

Additionally, the time dedicated to quality control is analysed. The simulation results indicate that the time spent on quality activities is 0.08 minutes for each HU in the as-is scenario, while in the to-be scenario in the receiving warehouse, it drops to zero.

Given that 60.5 % of 971 HUs undergo quality checks, the total time allocated to these activities amounts to roughly 47 minutes each day. Indeed, there are 587 inspected HUs, which multiplied by 0.08 minutes results in 46.99 minutes. As the information is integrated into the ERP, it is expected that the performance of the quality will not be affected.

An economic assessment can be estimated by considering scenarios with 4 operators instead of 5. Since the inspection time is reduced, resulting in 47 minutes not worked, this allows for cost savings. If an operator costs $15 per hour and works a total of 9 hours each day, minus the 47 minutes, then the total cost reduction is approximately $120 each day.

For this reason, we assert that assessing the performance of this activity through simulation is very helpful in understanding the impact of the activity's workflow. By adding information to the system, the workflow can be optimized to reduce lead time and increase the value of the tasks performed by the operators. Non-value-added activities can indeed be eliminated, allowing operators to engage in value-added tasks that enhance productivity and performance.

4. Conclusion and further directions

This study conducts a discrete event simulation to assess a CD process modification. The results demonstrate the impact of reducing quality control activities on overall operator utilization and efficiency. By lowering the proportion of time allocated to quality checks from 72% to 68%, workers can be reassigned to other logistical tasks, enhancing operational flexibility. Otherwise, it is possible to reduce one operator to maintain roughly the previous percentage of utilization of the as-is scenario. The total time spent and saved on quality control in the to-be scenario is quantified at 47 minutes, reflecting the distribution of workload across handling units. These findings indicate that optimizing quality control processes can improve workforce efficiency without compromising operational effectiveness.

It's important to acknowledge several limitations. First, further sensitivity analysis concerning various factors, such as the number of operators, should be conducted. Another limitation is that the simulation only examined two "To-Be" configurations with varying numbers of workers, which restricted the analysis of resource sharing. Finally, the assumption that the quality performance remains unaffected by the removal of inspection activities in the system was not validated.

Further research could investigate the potential impact of integrating digital twin technologies into the cross-docking process to enhance efficiency and decrease dependence on manual labour. Specifically, as noted by (Vaccari et al. 2024), the traceability of stock and vehicles using indoor positioning technologies could be a key area of interest. Additionally, examining the role of real-time data analytics in optimizing logistics operations could offer valuable insights into improving decision-making and response times. The implementation of digital cross-docking could further improve order tracking, ensuring precise traceability and proper storage throughout the process (Quiroz-Flores et al. 2022).

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