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Article

Streamlining logistics: Innovating cross-docking distribution systems for operational excellence

Albertus Laurensius Setyabudhi*, Humala Lodewijk Napitupulu, Rosnani Ginting, Meilita Tryana Sembiring

Department of Industrial Engineering, Universitas Sumatera Utara, Medan 20222, Indonesia
*** Corresponding author:** Albertus Laurensius Setyabudhi, alsetyabudhi@gmail.com

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Abstract: A logistics service company in Batam faces challenges related to warehouse load fulfillment and sorting inaccuracies. This study aims to identify proposed efficiency improvements to the goods distribution system using the cross-docking method. The research method chosen is cross-docking, a technique that eliminates the storage process in the warehouse, thus saving time and cost. The research findings show significant benefits, especially in achieving zero inventory efficiency. Data processing and discussion revealed that efficiencies were apparent by increasing the sorting tables from 1 to 6, with an output of 90,000 kg during aircraft loading and unloading (compared to approximately 77,000 kilograms). This efficiency arises from the larger output of the sorting tables compared to the input, eliminating the need for warehousing and adding ten trucks. As a result, the shipment can be completed in one trip, with no goods stored in the warehouse. The analysis shows that implementing cross-docking in the company increases efficiency in distributing goods to forwarding partners.

Keywords: cross-docking; efficiency; logistics system

1. Introduction

The logistics sector has a very strategic role in effective supply chain management. It is responsible for the smooth movement of goods from the production stage to the hands of the final consumer with optimal time efficiency and cost expenditure (Benrqya et al., 2020). Traditional distribution systems often involve multiple handling stages, storage facilities, and various modes of transport, which can result in increased transit times and operational costs (Kiani Mavi et al., 2020).

In these challenges, cross-docking has become increasingly prominent as a revolutionary approach (Castellucci et al., 2021). This method allows goods to be moved directly from the inbound to the outbound means of transport without requiring long-term storage in logistics facilities (Tirkolaeeet al., 2020). Cross-docking shortens the time required to deliver goods to their final destination and significantly reduces overall operational costs (Goodarzi et al., 2020).

Potential advantages of cross-docking include improved efficiency of the logistics process, reduced risk of damage or loss of goods during storage, and increased responsiveness to changes in market demand (Shahabi-Shahmiri et al., 2021). The growing attention to this method reflects the drive to streamline and optimize supply chain operations across the board, bringing positive benefits to companies and consumers (Kaboudani et al., 2020).

Despite the widespread awareness of cross-docking, there is an urgent need to delve into more comprehensive research and design implementation strategies that can be customized to the dynamics of different industries and business models (Zheng et al., 2021). The lack of understanding in optimizing and customizing cross-docking to respond to the unique challenges of each type of business is a critical point that must be addressed (Mukherjee et al., 2022).

It is important to explore further ways cross-docking can be effectively optimized to deliver maximum benefits (Theophilus et al., 2021). In this context, further research could explore aspects affecting cross-docking performance, such as integrating advanced technologies, efficient supply chain management, and adapting to changing market demands (Xi et al., 2020).

Knowledge gaps also exist regarding in-depth insights into the potential benefits and risks associated with adopting cross-docking in various logistics scenarios (Gunawan et al., 2021). Therefore, a thorough analysis is required to understand the impact of cross-docking on operational efficiency, cost, and response to market fluctuations (Dulebenets, 2021).

With more in-depth research, the industry can form more accurate and detailed guidelines, enabling smarter decision-making in implementing cross-docking strategies (Grangier et al., 2021). These steps will help create a solid foundation for the efficient and effective implementation of cross-docking in various logistics contexts (Gaudioso et al., 2021).

By understanding and delving deeper into the challenges faced by logistics service companies, this research aims to detail how cross-docking can be optimized in a specific operational context. The main focus is how companies can overcome warehouse load constraints and improve sorting accuracy to achieve operational excellence. Filling the gap in understanding the cross-docking concept in the operational context of logistics service companies has significant implications for the companies themselves and the logistics industry as a whole. This research is expected to make a major contribution to creating practical guidelines that can be applied by other logistics companies that may face similar challenges

2. Literature review

2.1. Cross-docking

Cross-docking is a logistics strategy that enables the direct transfer of goods from an inbound vehicle to an outbound vehicle without requiring long-term storage in a warehouse. According to Boysen and Fliedner (2010), cross-docking is a consolidation point in the distribution network where multiple small shipments are combined into one full truckload to save transportation costs. This definition emphasizes the economic efficiency of this method.

Cross-docking offers various advantages, including increased efficiency of the logistics process, reduced risk of damage or loss of goods during storage, and increased responsiveness to changes in market demand (Shahabi-Shahmiri et al., 2021). This method allows goods to be moved directly from the receiving vehicle to the sending vehicle without the need for long-term storage, which can reduce the time required to deliver goods to their final destination (Goodarzi et al., 2020).

The implementation of cross-docking requires careful planning and coordination. Research by Castellucci et al. (2021) shows that effective scheduling and the use of advanced technology can improve cross-docking performance. This research highlights the importance of proper timing of shipping and receiving goods to maximize operational efficiency.

Despite its many benefits, cross-docking also faces a number of challenges. According to research by Kaboudani et al. (2020), one of the main challenges is the coordination between the various parties involved in the process, including suppliers, shippers, and consignees. In addition, the lack of understanding on how to optimize and adapt cross-docking to the unique challenges of each type of business is also a critical issue that must be addressed (Mukherjee et al., 2022).

2.2. Scheduling in cross-docking

Cross-docking refers to the direct transfer of goods from the receiving vehicle to the sending vehicle without going through a long-term storage process. According to Boysen and Fliedner (2010), cross-docking serves as a consolidation point in the distribution network where small shipments can be combined into one full load to save transportation costs. Bartholdi and Gue (2004) add that this model allows deliveries to be made in less than 24 hours, and in some cases, even less than 1 hour.

Scheduling in cross-docking systems faces several key challenges, including synchronization of truck arrivals and departures, loading and unloading dock assignments, and handling arrival time uncertainty (Wisittipanich and Hengmeechai, 2017). Lee et al. (2006) mentioned that efficient scheduling is key to maximizing resource usage and reducing waiting times.

Recent research continues to explore the integration of advanced technologies such as the Internet of Things (IoT) and artificial intelligence (AI) in cross-docking scheduling. Theophilus et al. (2021) emphasized the importance of developing algorithms that can adapt to changing market dynamics and technology integration to improve cross-docking performance.

Scheduling in cross-docking systems is a complex and important research area in supply chain management. Various approaches have been developed to address these scheduling challenges. Future research should continue to explore the integration of advanced technologies to improve the efficiency and responsiveness of cross-docking systems.

2.3. Route in cross-docking

Cross-docking is a logistics distribution method that allows the transfer of goods directly from the inbound vehicle to the outbound vehicle without going through the storage process in the warehouse. According to Boysen and Fliedner (2010), cross-docking is a consolidation point in the distribution network where small shipments can be combined into one full load to save transportation costs. The concept focuses on improving efficiency by minimizing storage and speeding up the flow of goods from receipt to delivery (Bartholdi and Gue, 2004).

Route optimization in cross-docking involves scheduling vehicles and routes to ensure that goods can be delivered in the most efficient way. This optimization helps in reducing transportation costs, reducing delivery time, and increasing customer satisfaction (Maknoon and Laporte, 2017).

Baniamerian et al. (2019) presented a case study on the use of genetic algorithms for route optimization in a cross-docking system in the manufacturing industry. The results show that route optimization can reduce operational costs by up to 15%.

Although much research has been done, there are still challenges that need to be overcome, such as handling uncertainty in arrival and departure times, as well as the integration of new technologies such as the Internet of Things (IoT) for real-time tracking (Tirkolaee et al., 2020).

2.4. Placement optimization and multimodal in cross-docking

Placement optimization in cross-docking involves strategically arranging elements such as entrances and exits, sorting areas, and temporary racks to reduce handling time and improve the flow of goods. A study by Dobrusky (2003) showed that optimal siting of cross-docking centers can significantly reduce operational costs. Küçükoğlu and Öztürk (2017) developed a two-stage optimization method that successfully reduced handling time and improved operational efficiency. In addition, Yu et al. (2016) found that placement optimization using particle swarm algorithm can reduce transportation costs and delivery time.

The multimodal approach in cross-docking involves the use of various modes of transportation to optimize the distribution of goods, increasing the flexibility and responsiveness of the supply chain. Li et al. (2009) showed that a combination of transportation modes can increase efficiency and reduce transportation costs. Pawlowski (2015) investigated the integration of multimodal transportation in cross-docking systems and found that it can reduce transit time and logistics costs. Maknoon and Laporte (2017) developed an optimization model that improves the efficiency of freight delivery through optimal utilization of different modes of transportation. Overall, optimizing the placement and use of multiple modes in cross-docking can provide significant improvements in logistics operational performance.

3. Methodology

This research uses a quantitative approach with a case study design to analyze the efficiency of the cross-docking distribution system at PT KLM Logistik, a Batam-based logistics company. This approach was chosen because it allows in-depth analysis of phenomena in a real operational context.

The study population included all goods delivery activities carried out by PT KLM Logistics in Batam. The sample was taken from the goods accumulated in the warehouse, totalling 97 units. The sampling technique used is purposive sampling, where the sample is selected based on certain criteria relevant to the research objectives, such as shipping volume, type of goods, and shipping routes.

Data collection in this study used three main instruments: survey, documentation, and observation. Surveys were used to collect quantitative data from PT KLM logistics employees directly involved in the cross-docking process. The documentation in the form of secondary data was collected through documentation, including historical records, shipping manifests, and official company archives. Furthermore, direct observation was conducted to collect qualitative data regarding the operational process in the field. This involved observing the sorting and distribution of goods, interactions between staff, and the overall workflow.

The Data Collection stage is carried out by interviewing employees of PT KLM logistics to collect primary data, Collecting secondary data that supports the design of the cross-docking distribution system, including official documents, records, and archives, and Conducting direct observations to record the processes and interactions that occur during the delivery and sorting of goods.

The data were analyzed by descriptive analysis, presented in tabular form to describe the frequency distribution of the research variables, and then analyzed using the Time Efficiency test.

This study has two types of variables: independent variables and dependent variables. The independent variables are the sorting table and the amount of packing. The dependent variable is the storage distribution time.

4. Results

4.1. Warehouse distribution system

The term "air freight logistics" pertains to the transfer and transportation of goods via air carriers, whether they are chartered or commercial flights. This method is favored in the logistics sector because it allows packages to be dispatched from commercial and passenger aircraft hubs to any destination accessible by air. Cargo planes are essential in this system, guaranteeing the timely delivery of various goods, including medical supplies and everyday essentials. These freight aircraft are crucial to the global logistics network, facilitating quick and dependable transport over long distances. More details can be seen in **Table 1** below:

Table 1. Details of goods distribution.

Distribution of Goods for Aircraft Logistics Services	Goods Allocation Calculation
a. Expedition aircraft logistics services, turnover at 10 expedition partners ±14,000kg per week. b. Loading and unloading routes to batam from • Eastern region: Surabaya • West region: Jakarta • Sumatra region: Medan, Deli Serdang and Pekanbaru. c. The aircraft can hold ± 233,000 kg of goods. d. The aircraft did 2 loading and unloading of goods in a day in Batam. e. The logistics service company has 1 truck/partner, a total of 10 trucks for 10 partners. f. 1 truck loads ± 13 pallets, 1 pallet contains 15 sacks, 1 sack weighs ± 20 kg. g. The aircraft unloaded one item weighing ± 77,000 kg. h. There are 5 sorting tables, 1 sorting table is capable of sorting ± 15,000 kg in a day.	a. Sorting table 15,000 kg × 5 = 75,000 kg/loading once a day. 75,000 × 2 = 150,000 kg for overtime work, Still remaining 2000 kg unsorted × 7 days = 14,000 kg buffer/stored in the warehouse. b. Delivery per truck 75,000:3900 kg = 19 trucks, while we have 10 trucks. If a delivery is made, the truck makes 2 deliveries to the expedition partner.

The X aircraft expedition has carefully planned and introduced a buffer system in its main warehouse to enhance its logistics operations. This strategic move aims to manage the flow of goods more effectively, preventing bottlenecks and ensuring a seamless process.

The buffer system functions on a weekly cycle, which helps in organizing and predicting the flow of cargo. With a capacity to hold up to 14,000 kg of cargo, this system is designed to handle substantial volumes of goods, ensuring that there is always a reserve to meet demand.

By incorporating this buffer, the expedition significantly improves the overall efficiency of its logistics operations. The buffer acts as a cushion, absorbing fluctuations in cargo volume and preventing disruptions in the supply chain. This leads to a more stable and predictable logistics process.

The buffer system also contributes to more efficient handling of goods. It allows for better organization within the warehouse, making it easier to manage incoming and outgoing shipments. This efficiency reduces handling times and minimizes the risk of errors or delays.

One of the primary benefits of the buffer system is the ability to ensure timely deliveries. By maintaining a reserve of cargo, the expedition can quickly respond to urgent requests and maintain delivery schedules. This reliability is crucial for meeting customer expectations and maintaining service quality. For more details can be seen in **Figure 1**.

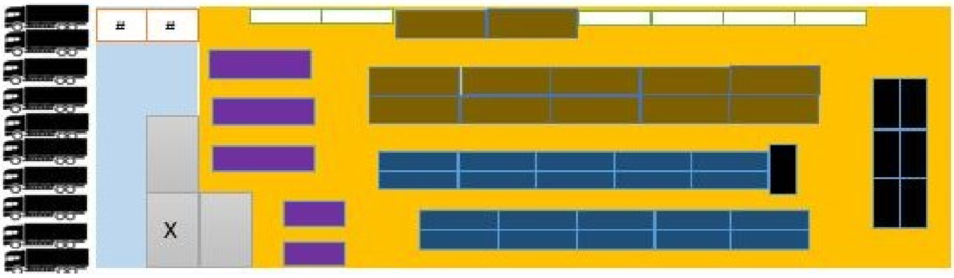

Figure 1. Main warehouse floor plan as a distribution center.

Description:

One major inefficiency is the handling of incoming goods. The main warehouse receives shipments not only for the primary partner but also for other partners, leading to confusion and a lack of clear allocation. This indiscriminate storage approach complicates inventory management and disrupts the warehouse's efficiency.

The allocation of storage space is done based on a fixed percentage rather than the specific types of goods. This method overlooks the unique needs of each partner, who may have different categories and specifications for their products. Such a generalized allocation system fails to address the distinct requirements of each partner, resulting in suboptimal storage and handling practices.

Another significant problem is the presence of goods in long-term storage due to the irregular and disorganized placement of items. The lack of a systematic storage strategy leads to inefficient use of space and resources, making it difficult to access and manage these goods promptly.

The overall flow of goods and information within the warehouse is impacted by these inefficiencies. A clear and organized system is essential for smooth operations, but the current setup hinders effective tracking and movement of items. The disjointed flow of goods and information contributes to delays and errors, affecting the overall performance of the warehouse. Flow of goods before cross-docking design can see in **Figure 2**.

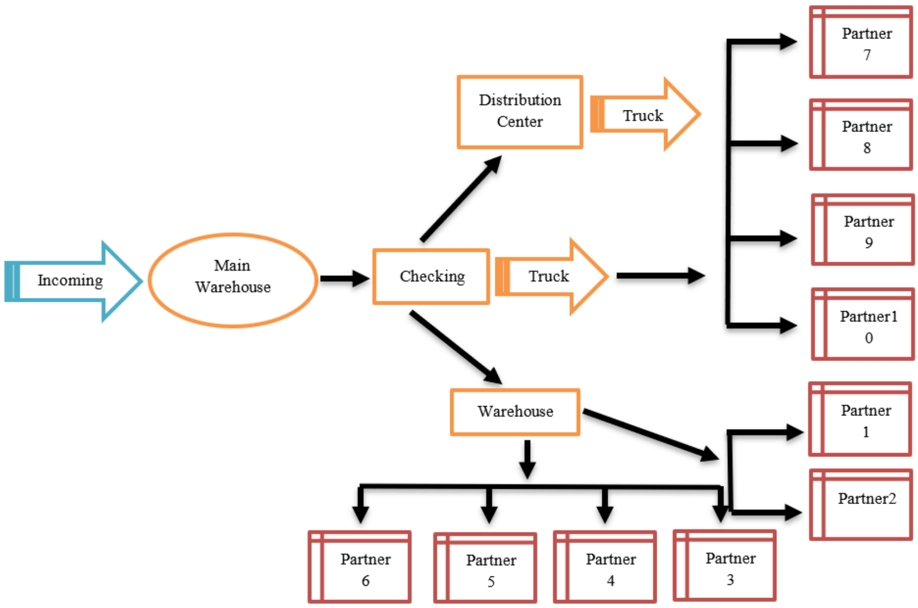

Figure 2. Goods flow.

When goods arrive at the main warehouse, they are first directed to the checking and sorting area. This initial step is crucial as it involves inspecting each item to ensure they meet quality standards and categorizing them based on specific criteria. The sorting process is meticulous, ensuring that each item is correctly identified and classified.

Once the goods have been checked and sorted, they are distributed to one of two warehouse categories. The first category is the large warehouse, which is designed to store substantial quantities of goods, providing ample space for bulk storage. The second category is the mutation warehouse, which handles items that require more dynamic storage solutions due to frequent movement or special handling requirements. More details can be seen in **Figure 3**.

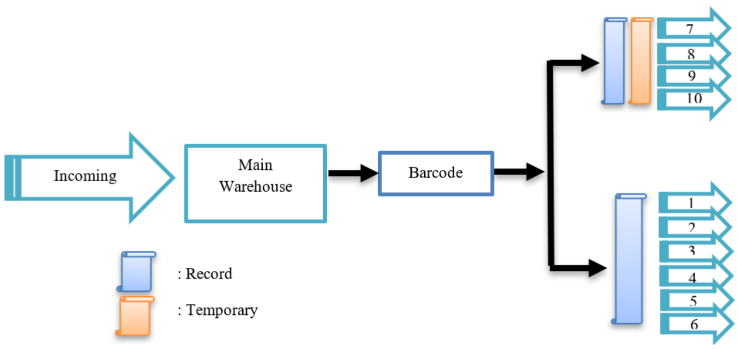

Figure 3. Old job process.

After the goods have been allocated to their respective warehouses, the next step involves preparing them for distribution to the expedition partners. Each partner receives a tailored shipment, ensuring that the correct goods are delivered to the right destination efficiently. This organized and systematic approach ensures that the entire process, from arrival at the main warehouse to final distribution, is streamlined and effective, minimizing delays and errors.

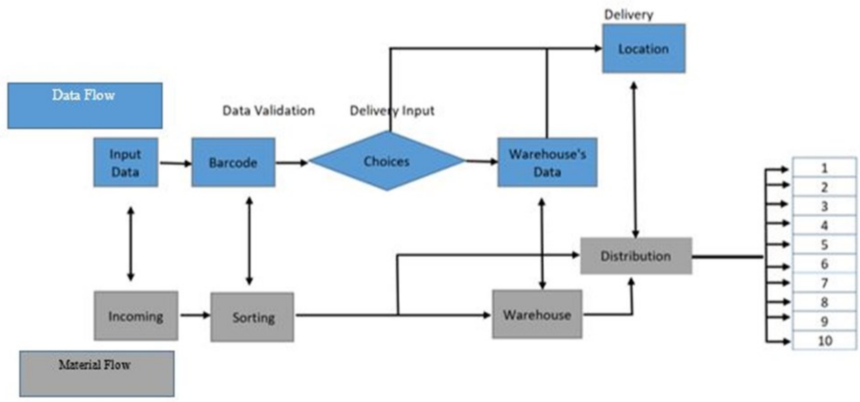

Figure 4. Goods flow and information flow before cross-docking design.

Figure 4 above illustrates that the operations are segmented into two main streams: the movement of goods and the transmission of information. The sequence of the goods' movement is outlined below:

(1) Incoming, goods are unloaded from the aircraft and transported to the sorting area for further processing.

(2) Admin Sort, upon arrival, goods undergo administrative sorting where they are inspected, verified, and validated.

(3) Warehouse, following administrative sorting, the goods are then transferred to the storage warehouse for temporary storage.

(4) Distribution, after being sorted and stored, the goods are promptly dispatched directly to the respective partners for delivery.

The information flow within this operation is outlined as follows:

1) Input Data

2) Barcode for validation data

3) Choice, during this stage decisions are made regarding the selection of input data destined for warehousing or outbound delivery to customers)

4) Warehouse

5) Distribution

4.2. Distribution cross-docking system design

The primary objective of the cross-docking system is to facilitate the direct delivery of goods to partners, bypassing the need for storing them in the distribution center warehouse. This approach streamlines the logistics process, enhancing efficiency by minimizing storage time and handling costs. Instead of being temporarily stored, incoming goods are swiftly sorted and transferred directly to outbound transportation, expediting their journey to the intended recipients. This strategic method optimizes the supply chain, promoting timely deliveries and reducing unnecessary inventory holding (Benrqya et al., 2020; Castellucci et al., 2021).

Figure 5 illustrates the expansion of sorting facilities and transportation resources. One table for sorting has been incorporated, alongside the introduction of 10 additional trucks, resulting in each partner now having a total of 2 expedition trucks dedicated to delivering goods packages. This expansion aims to bolster the logistics capabilities, ensuring that partners have sufficient resources to efficiently handle and transport their shipments. With enhanced sorting facilities and an increased fleet of trucks, the logistics process is poised to accommodate higher volumes of goods, enabling smoother operations and timely deliveries to customers.

a With 15 sorting tables each capable of handling 15,000 kg, the total capacity for one cycle of loading and unloading amounts to 90,000 kg per day. In the event of overtime work, the combined capacity becomes 150,000 kg (75,000 kg multiplied by 2). Consequently, considering this increased capacity, goods weighing up to 180,000 kg can be efficiently sorted without necessitating warehouse storage, as this figure surpasses the 150,000 kg threshold. This strategic utilization of sorting resources ensures that the cross-docking process remains uninterrupted, allowing for the swift and seamless distribution of goods directly to partners.

b To accommodate the delivery of goods, each truck is capable of transporting up to 75,000 kg. With a maximum capacity of 3900 kg per delivery, the calculation indicates a requirement for 19 trucks to fulfill the task. This comprises the existing fleet of 10 trucks, supplemented by an additional 10 trucks specifically allocated for transporting goods, thereby ensuring that no items need to be stored within the facility. This augmentation of transportation resources optimizes the distribution process, guaranteeing swift and efficient delivery of goods to their respective destinations without the need for interim storage.

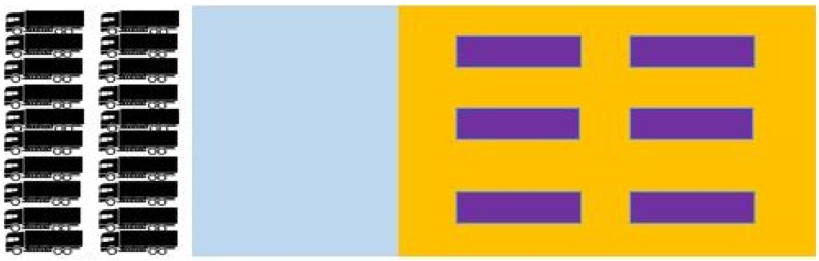

Figure 5. Distribution center plan.

Description:

 : Truck

 : Working Area

The key distinction between the current cross-docking distribution system and its predecessor lies in the absence of storage shelves for goods and the addition of several workstations. This modification signifies a shift towards a more streamlined and efficient approach to handling goods, emphasizing rapid sorting and immediate dispatch. By eliminating the need for storage shelves, the system minimizes delays and optimizes space utilization, while the inclusion of extra workstations enhances processing capacity, enabling faster throughput and smoother logistics operations overall (Darvishi et al., 2020; Gaudioso et al., 2021). A comprehensive overview of the goods distribution administration system within the distribution center (DC) is provided below **Figure 6**:

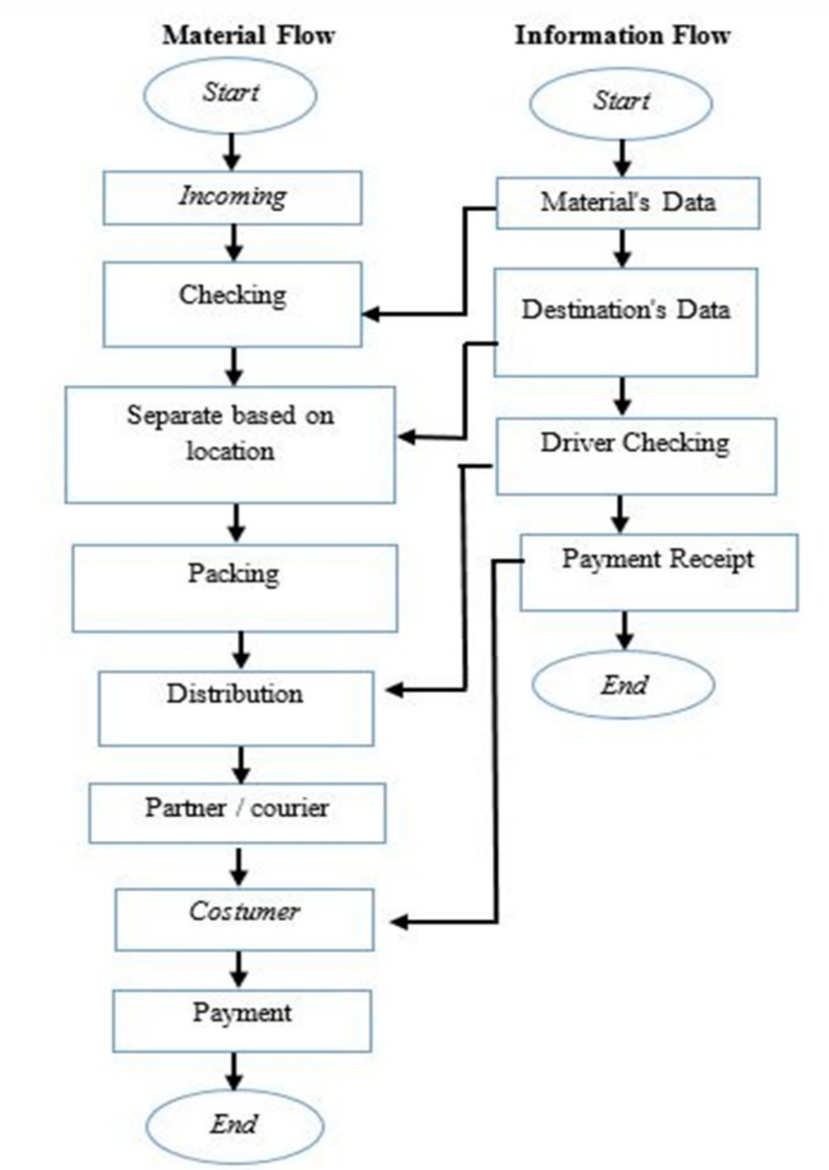

Figure 6. Flowchart crossdocking distribution system.

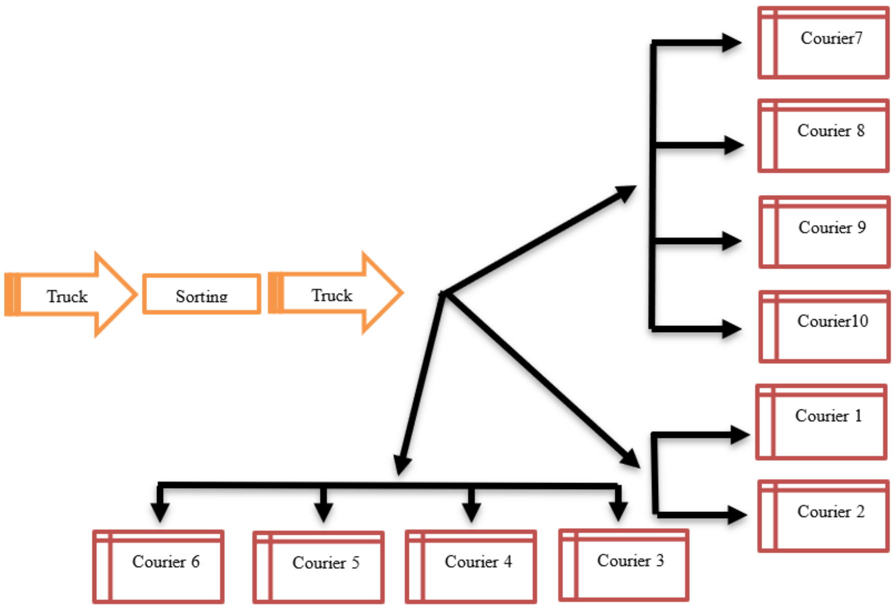

Figure 7. The process of goods flow and recording for partner shipments unfolds.

The illustration in **Figure 7** depicts the distribution of goods using the cross-docking method, which eliminates the need for storage or warehouse space. The key contrast between the previous distribution flow and the updated design lies in the absence of any storage location for goods. In this revised distribution process, goods are delivered directly to the sorting point and promptly distributed to expedition partners, thereby eliminating the need for storage entirely. This refined approach ensures that goods are swiftly transferred to their respective destinations without any interim storage, enhancing efficiency and minimizing handling time (Mukherjee et al., 2022; Nurprihatin et al., 2021).

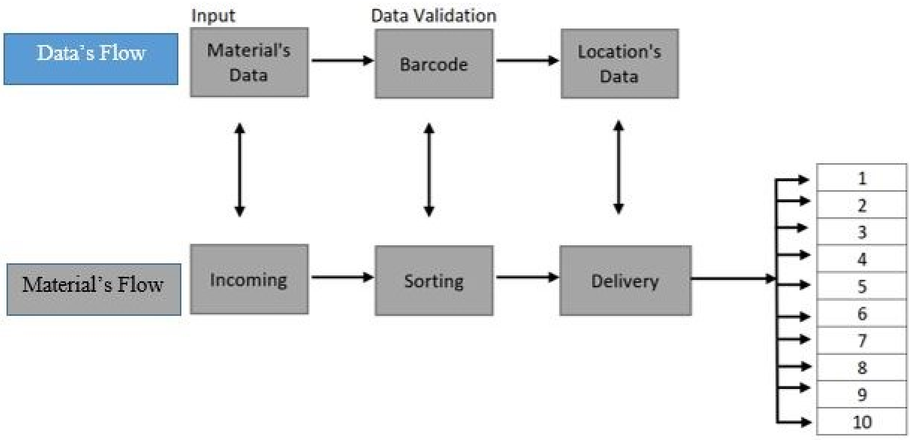

Figure 8. Flow of goods and information post-cross-docking design.

Figure 8 illustrates the significant transformation in both the flow of goods and the flow of information following the implementation of the cross-docking design. This streamlined approach has revolutionized the logistics process, ensuring seamless coordination between the movement of goods and the transmission of essential data.

Now, goods flow swiftly through the system, bypassing the need for intermediate storage, while information flows seamlessly to facilitate efficient tracking and management. This enhanced integration between goods flow and information flow optimizes the overall efficiency of the distribution process, enabling faster delivery times and improved customer satisfaction.

In the depicted illustration, it delineates the arrival of goods, followed by the barcode scanning process. Subsequently, the data input comprises information regarding the shipment of goods and the identification of items. This data is then transmitted to each expedition partner, facilitating efficient coordination and ensuring that the necessary information is promptly communicated to all relevant parties.

4.3. Data calculation

Upon reviewing the data in **Table 2**, a clear difference emerges between the previous system and the system designed with the cross-docking methodology. The data curated under the cross-docking system showed a marked improvement in efficiency. In particular, there was a marked reduction in the number of items occupying the sorting table, indicating a more efficient and organized process. In addition, the amount of packaging materials used showed optimization, reflecting a concerted effort to minimize waste and improve resource utilization.

Table 2. Using the crossdocking method.

No	Number of items on the sorting table	Packing Quantity (unit)	storage distribution time (minutes)
1	32	73	11
2	35	72	12
3	35	74	11
4	32	73	12
5	33	72	11
6	34	73	12
7	35	72	11
8	32	74	12
9	35	73	11
10	35	72	12
11	32	74	11
12	33	72	12
13	34	74	11
14	32	73	12
15	32	73	11
16	33	72	12
17	35	72	11
18	32	74	12

Table 2. (*Continued*).

No	Number of items on the sorting table	Packing Quantity (unit)	storage distribution time (minutes)
19	33	73	11
20	34	72	12
21	34	74	11
22	32	72	12
23	35	74	11
24	35	73	12
25	32	72	11
26	33	73	12
27	34	72	11
28	35	74	12
29	32	73	11
30	35	73	12
31	35	72	11
32	32	72	12
33	33	74	11
34	34	73	12
35	33	73	11
36	32	72	12
37	35	72	11
38	35	74	12
39	32	73	11
40	33	74	12
41	34	72	11
42	34	72	12
43	32	74	11
44	35	73	12
45	35	73	11
46	32	73	12
47	33	72	11
48	34	74	12
49	32	73	11
50	32	74	12
51	35	74	11
52	35	72	12
53	32	74	11

Table 2. (*Continued*).

No	Number of items on the sorting table	Packing Quantity (unit)	storage distribution time (minutes)
54	33	73	12
55	34	72	11
56	33	73	12
57	32	72	11
58	35	74	12
59	35	73	11
60	32	74	12
61	33	72	11
62	34	72	12
63	34	74	11
64	32	73	12
65	35	72	11
66	35	74	12
67	32	72	11
68	33	74	12
69	34	73	11
70	32	72	12
71	32	73	11
72	33	72	12
73	34	74	11
74	34	73	12
75	32	72	11
76	35	74	12
77	35	72	11
78	32	74	12
79	33	73	11
80	34	72	12
81	32	73	11
82	32	72	12
83	33	74	11
84	34	73	12
85	33	72	11
86	32	74	12
87	35	72	11
88	35	74	12

Table 2. (*Continued*).

No	Number of items on the sorting table	Packing Quantity (unit)	storage distribution time (minutes)
89	32	73	11
90	33	73	12
91	34	72	11
92	34	73	12
93	34	72	11
94	32	74	12
95	35	73	11
96	32	72	12
97	33	74	12

Table 3. Data normality test.

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Sorting Table	0.313	97	0.000	0.748	97	0.000
Packing Quantity	0.343	97	0.000	0.636	97	0.000
Storage distribution time	0.343	97	0.000	0.636	97	0.000

Table 3 above shows the normality test of the research data after cross-docking was applied to the existing distribution system. From the data normality test obtained, it is known that the data is not normally distributed. Where seen from the sig value on the Kolmogorov-Smirnov test is less than 0.05. This is because, indeed, in this distribution, it must be conditioned that the goods sent do not exceed the capacity of the aircraft, and there cannot be too many of them. So, it cannot follow the existing normal distribution.

Table 4 shows Cronbach's Alpha of these three things is greater also than 0.6. For the reliability test, it can be seen from the Cronbach's alpha, if the Cronbach alpha is more than 0.6 then it is said to be reliable. Cronbach's Alpha obtained was 0.658 which means it is greater than 0.6.

Table 4. Reliability test.

Cronbach's Alpha	N of Items
0.658	3

On the sorting table the data retrieved is the number of sort admins used at the time of data retrieval. This will certainly affect the sorting time of the goods that arrive, this will indirectly certainly affect the existing distribution time. The number of packings is data on the number of goods coming or entering from planes coming to the Batam area. At the time of distribution, the storage loading data the length of the distribution takes place after implementing the cross-docking design that has been designed.

Table 5. Validity test.

		Sorting Table	Packing Quantity	Storage distribution time
Sorting Table	Pearson Correlation	1	–0.281**	0.905**
	Sig. (2-tailed)		0.005	0.000
	N	97	97	97
Packing Quantity	Pearson Correlation	–0.281**	1	0.010
	Sig. (2-tailed)	0.005		0.921
	N	97	97	97
Storage distribution time	Pearson Correlation	0.905**	0.010	1
	Sig. (2-tailed)	0.000	0.921	
	N	97	97	97

The **Table 5** above has been declared valid because it is in accordance with the provisions of the validity and reliability test. The basis for taking the validity test consists of two provisions, namely:

1) Pearson validity test (If the value of r count is more than r table = valid)

2) The significance value is 5% (If the significance value is less than 0.05 = valid)

The following is a design of the number of goods using the cross-docking method.

$$\frac{\text{Total time}}{97} \times 100\% = \frac{1116}{97} \times 100\% = 12\% \text{ (Time efficiency)}$$

The difference in the details of the data from the previous one is that data designed using a cross-docking system is more efficient due to the loss of 12% time in storing goods that will be stored on shelves, making the system work faster in sending goods to customers directly.

5. Discussion

Based on the results of the research that has been conducted, the implementation of the cross-docking system at PT KLM Logistics has shown a significant increase in efficiency in the distribution of goods. The addition of sorting tables from one to six tables has increased the sorting output to 90,000 kg during the loading and unloading process, which is significantly higher than the input of goods, around 77,000 kg. This efficiency is achieved because the output of the sorting tables is greater than the input, so no goods need to be stored in the warehouse, and the distribution process can be done faster.

In addition, the data normality test using Kolmogorov-Smirnov shows that the data is not normally distributed with a significant value of less than 0.05. However, this is acceptable because the data on the distribution of goods must be adjusted to the capacity of the aircraft and cannot be too much. The reliability test using Cronbach's Alpha shows a value of 0.658, greater than 0.6, indicating that the data used in this study is reliable. The Pearson correlation validity test shows that all measured variables have a significant relationship, with a significant value of less than 0.05, indicating high data validity.

However, several challenges need to be considered in the implementation of cross-docking. One is effective coordination between the various parties involved in the process, including suppliers, shippers, and consignees. Research by Kaboudani et al. (2020) emphasized the importance of good coordination in overcoming this challenge. In addition, the adaptation of advanced technologies such as the Internet of Things (IoT) and artificial intelligence (AI) in scheduling and managing cross-docking can further improve the efficiency of the system, as suggested by Theophilus et al. (2021).

This research also underscores the importance of placement optimization in cross-docking. A study by Dobrusky (2003) showed that determining the optimal location of cross-docking centres can significantly reduce operational costs. Küçükoğlu and Öztürk (2017) developed a two-stage optimization method that successfully reduced handling time and improved operational efficiency. Yu et al. (2016) found that particle swarm algorithm placement optimization can reduce transportation costs and delivery time.

Multimodal approaches in cross-docking also play an important role in improving supply chain flexibility and responsiveness. Li et al. (2009) showed that combining transportation modes can improve efficiency and lower costs. Pawlowski (2015) found that integrating multimodal transportation in a cross-docking system can reduce transit time and logistics costs. Maknoon and Laporte (2017) developed an optimization model that improves the efficiency of freight delivery through optimal utilization of various transportation modes.

Overall, this study confirms that cross-docking can significantly improve logistics operational performance with optimal placement strategies and the use of multiple transportation modes. Further research is needed to explore integrating advanced technologies and developing adaptive algorithms that can respond to changing market dynamics to further improve cross-docking performance.

6. Conclusion

This study aims to improve the efficiency of the distribution system at PT KLM Logistik by implementing the cross-docking method. The results show that the implementation of a cross-docking system can provide various significant benefits in terms of operational efficiency and cost reduction.

Before implementing a cross-docking distribution system, it is imperative to conduct a thorough assessment of the existing warehouse infrastructure. This step involves identifying the old warehouse's key functions and operational processes. In the context of PT KLM Logistik, the old warehouse faced frequent overload issues and sorting errors. Hence, it was necessary to create a detailed schematic that sequentially depicts the tasks and workflow arrangement of goods distribution. This schematic helps in understanding the weak points of the old system and designing a new, more efficient system.

A structured approach should be followed to clarify the process at the design stage of a new distribution centre. This includes conducting interviews with relevant parties to identify and prioritize the distribution centre's needs. In this study, the researcher interviewed the operational and management staff of PT KLM Logistik to gain insight into the needs and operational challenges faced. By involving key parties, the design process can accurately reflect the operational needs and goals of the organization. This process also ensures the new system can address existing issues and improve efficiency.

Implementing a cross-docking system offers significant benefits in terms of time savings. By streamlining the workflow and eliminating unnecessary storage steps, the system can speed up the distribution process. For example, this study showed that by increasing the number of sorting tables from 1 to 6, the sorting output can reach 90,000 kg in one loading and unloading cycle, compared to an input of approximately 77,000 kg. These efficiency gains translate into reduced waiting times and increased operational productivity, ultimately improving the overall performance of the distribution centre. In addition, by adding 10 trucks, the delivery of goods can be made in one trip, resulting in no goods being stored in the warehouse.

In addition to time efficiency, cross-docking systems also contribute to reduced operational costs. By reducing the need for long-term storage of goods, inventory management and warehouse maintenance costs can be significantly reduced. This study found that by eliminating the need to store goods, PT KLM Logistik can reduce operational costs and improve resource use efficiency.

The cross-docking system enables increased responsiveness to changes in market demand. With a faster flow of goods and reduced storage time, companies can more quickly respond to customer demand and changing market conditions. This provides a competitive advantage in the highly dynamic logistics industry.

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