Decision support system for truck scheduling in logistic network through cross-docking strategy

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Abstract. In recent years, companies around the world need to find new ways to reduce costs, increase productivity, improve product quality, and meet various customer demands. Each Distribution Center (DC) or warehouse is specifically designed to minimize costs in the company's supply chain. Cross-docking is a logistics technique that eliminates storing and picking up items at warehouses. Cross-docking has several advantages compared to other product distribution strategies from both an economic and an environmental point of view. Cross-docking decisions are influenced by many factors such as the level of product demand, the cost of stock-outs, and the distance from suppliers to customers. This research builds a Decision Support System (DSS) that can help companies to ensure sustainability in the supply chain. This study assumes the demand is deterministic which is indicated by Economic Order Quantity (EOQ). This system can detect the time and quantity of certain items that experience cross-docks accurately. If the customers' demand cannot be fulfilled by the warehouse, then the goods are categorized as out of stock. By knowing the time and quantity of goods at the time of the cross-dock, the warehouse manager can make operational decisions quickly and accurately related to the resources such as operators and forklifts.

1. Introduction
In recent years, companies around the world need to find new ways to reduce costs, increase productivity, improve product quality, and meet various customer demands [1]. As the number of demand keeps increasing, it is logical that the competition between manufacturers is going to be incisive [2]. In addition to the economic aspects, factors that need to be considered are improving customer service, increasing efficiency, reducing waste, and focusing on customer satisfaction [1,3,4]. Waste can be interpreted as all activities that do not provide value-added activities [5]. Strategies to reduce costs and increase profits can be achieved through efficient supply chain management [6]. Distribution is the mechanism which products and services are transferred from producers to end consumers [7]. A previous study tried to minimize the distribution costs alongside the distance traveled [8]. In more detail, the focus on distribution network design is important in order to optimize product flow in minimizing costs [9]. The distribution center (DC) or warehouse plays the most important role in the distribution stage [10].
Each DC or warehouse is specifically designed to minimize costs in the company's supply chain[11]. There are four main activities in the warehouse, such as receiving, storage, picking, and shipping [3,12]. Storage and order-picking are usually the most costly activities because they are intensive[3]. Therefore, choosing the right warehouse strategy can determine warehouse performance and meet customer needs[12]. Furthermore, scheduling strategies are important because they can increase product flow, reduce unnecessary waiting times, and reduce waiting times for product deliveries to customers[13].

Cross-docking is a logistics technique that eliminates storing and picking activities at warehouses[10,14]. With this technique, products are sent to the warehouse with inbound trucks which are firstly sorted and rearranged based on customer requests, then transferred and loaded to outbound trucks to be sent to customers without being stored in the warehouse[13,15]. In other words, this technique moves products directly from inbound trucks to outbound trucks with little or no storage[9,10]. Sometimes, this technique is used if the goods are in the warehouse for less than one hour, or less than 24 hours[9,10,12,13,16], or less than 36 hours[1], or less than 48 hours[11].

Cross-docking has several advantages compared to other product distribution strategies from both an economic and an environmental point of view[9]. Compared to traditional warehouses, cross-docking systems can reduce product storage and retrieval costs by integrating the flow of trucks in and out[13,16]. Other typical advantages are a decrease in inventory levels, operational costs, and delivery time or an increase in throughput and customer satisfaction[13]. This advantage can benefit companies with little or no warehouse capacity[10].

Cross-docking decisions are influenced by many factors such as the level of product demand, the cost of stock-outs, and the distance from suppliers to customers. A previous study discussed several expectations of customer service that need to be fulfilled [17]. This mode of operation usually consists of the number of discrete items in the inbound and outbound[14]. In more detail, previous studies emphasized the importance of making cross-dock operational decisions and distribution network decisions simultaneously[18].

Another study suggested the development of information and technology in improving the quality of work[19]. A Decision Support System (DSS) can help companies to ensure sustainability in the supply chain[20]. In making decisions, it is also important to observe the condition of the supply chain and the available inventory in the warehouse[6]. The cross-docking terminal must coordinate three decisions that are tightly combined, such as[21]:

- Delivery of goods from suppliers to the cross-dock terminal.
- The process of consolidation on the cross-dock terminal.
- Delivery of spare parts from the cross-dock terminal to one or several destinations.

This research discusses inventory policies by considering cross-docking strategies. This study also addresses the problem of scheduling several inbound and outbound trucks simultaneously. The assumption in this study is that demand is deterministic. The idea of cross-dock aims to avoid the traditional functions of the warehouse such as storage costs and handling costs, as discussed in this study.

2. Literature review

Cross-docking is classified into 3 (three) categories based on the level of decision making, such as[3,20]:

- **Strategic level.** At the strategic level, decisions are made in the scope of long-term planning, such as determining the location, form of facilities, and layout of the cross-docking terminal.
- **Tactical level.** At the tactical level, the discussion focuses on cross-docking networks to distribute products.
- **Operational level** At the operational level, decisions are short-term such as scheduling trucks and other vehicles within a daily or weekly period.
Problems at the tactical and operational levels raise various issues such as determining the collaboration of the number of shipments of goods between suppliers and receivers, and multi-mode transportation planning, and their routes[20]. Another study discussed the feasibility study of the pipeline network[22]. This study discusses the cross-docking problem at the operational level, focusing on the truck schedule.

At a strategic level, previous research discussed the location selection of cross-docking terminals using the Intuitionistic Fuzzy Hierarchical Group Decision-Making (IFHGDM) model[23]. Previous research aims to determine the location of cross-docking terminals from several prospective locations[23]. At the tactical level, previous studies have discussed reverse logistics in an industrial area. A Mixed-Integer Linear Programming (MILP) was developed to optimize the total costs consisting of fixed costs during the construction of cross-docking terminals and transportation costs[15]. At the operational level, the development of simulation models, mathematical models, and DSS had been carried out. Simulation models were used to minimize costs by comparing policies against employees with permanent and non-permanent assignments[11]. Another study proposed measurement tools that can be used in cross-docking terminals by illustrating holistic operations on simulation models[18].

Mathematical models were generally discussed to minimize transportation costs by considering various things. Previous study considered penalty fees[16], transport capacity, and time window[3]. Time window factors and customer satisfaction had also been discussed simultaneously[4].

Previous research discussed the development of mathematical models with diverse objectives. Previous studies discussed the time of delivery to minimize the delivery time considering earliness and tardiness[9,13]. Tardiness issue was successfully tackled using heuristics method in production scheduling[24]. There are also studies that aim to determine the optimal number of kanban or card in Japanese[1], and minimizing the usage of the transportation mode[25]. The transportation mode capacity may be assumed homogeneous[26] or heterogeneous which can affect the lot sizing. This study considers the deterministic lot sizing. Previous research found that the mathematical model is able to solve problems at the operational level by considering Economic Order Quantity (EOQ)[6,14].

Studies that develop DSS had been conducted with different objectives. Previous research tried to maximize the level of goods loading by taking into account the limited supply of rail transportation[27]. Similar research was conducted to establish collaboration between interested parties in making decisions[20].

This study aims to create a DSS in avoiding the traditional functions of the warehouse such as storage costs and handling costs. This study assumes that demand is deterministic in terms of EOQ. In previous studies, independent EOQ lot sizes reached near-optimal solutions[14].

This research can help companies in making decisions from an operational level. This research is also the first step in developing a decision-making model up to the tactical and strategic stages. As an illustration, the company can later manage the conditions of inventory and resources in the warehouse in serving suppliers and consumers.

3. Methodology
The research procedure started with the identification of data requirements and followed by data collection methods and techniques, and data processing. At the problem identification stage, the recent development of a DSS at the warehouse by considering cross-docking is discussed. The scope of this research is warehousing activities involving suppliers and consumers. At the literature study stage, a collection of material, data, and information from related books and scientific articles is carried out while strengthening the understanding of cross-docking theory, the development of previous research, and the development of DSS. At the same time, the demand is assumed to be deterministic based on the EOQ calculation. Next is the identification phase of data requirements, such as the number of demand in a year, the ordering cost, and the handling cost as shown in Figure 1. After the data is collected, DSS is developed under the System Development Life Cycle (SDLC) with the waterfall model. The waterfall model is the oldest and most well-known model in SDL[28]. At the final stage, the waterfall is tested so that it is in accordance with the requirements of the DSS. Next, the analysis and recommendation of resources used in the warehouse are carried out.
This paper used the dummy data as a numerical test. From these data, behavior can be obtained from DSS towards extreme numbers. Although the limited number of players still can deliver values to customer [29], the number of suppliers and customers can vary [1]. The structure of the problem can be one-to-one when there is only one supplier serving one customer, one-to-many with one supplier and several customers, or many-to-many with multiple suppliers and several customers [1].

4. Results and discussion

4.1. Context diagram
Data-flow diagrams (DFD) are usually developed using a tiered method. Starting with the Context Diagram (CD), DFD level 1, DVD, level 2, DVD level 3, and so on in accordance with the complexity of the system to be developed. This study only covers CD and DFD level 1. Figure 2 explains CD or DFD level 0. The warehouse manager will interact with the DSS so that it is able to adjust resource requirements at a certain time.

4.2. Data-flow diagram
Figure 3 shows the level 1 DFD which is used as input for information and knowledge to be followed up by the warehouse manager in his actions. Level 1 DFD describes more specific DSS systems, such as master data manipulation, ordering data manipulation, and cross-docking checks.
4.3. Flowchart
The flowchart for making DSS is shown in Figure 4. The first process starts from manipulating the master data which will produce a database of supplier and consumer identities. Furthermore, users can manipulate ordering data from both the supplier and consumer side. Finally, cross-docking checks are carried out while simultaneously displaying the status of a lack of items.

4.4. Master data

4.4.1. Supplier data. This tab is useful for inserting, editing, and deleting supplier data. On this tab, users will be asked to enter the supplier ID, supplier name, supplier email, and supplier address. The contents of the supplier table are displayed on the right side of the supplier tab.

4.4.2. Customer data. This tab is useful for inserting, editing, and deleting customer data. On this tab, users will be asked to enter their customer ID, customer name, customer email, and customer address. The contents of the consumer table are displayed on the right side of the customer tab.

4.4.3. Item data. This tab is useful for inserting, editing, and deleting data on manufactured goods (items). On this tab, users will be asked to enter item ID, supplier ID, supplier name, item name, item price, item selling price, and storage cost. The contents of the item data table are displayed on the right side of the item tab.
Figure 4. Flowchart

4.5. Item order data

4.5.1. Supplier order. This tab is useful for inserting, editing, and deleting supplier order data. In this tab, the user will be asked to enter the supplier ID (selected via the dropdown list), goods ordered through the supplier (via the dropdown list), the annual demand, order price, lead time, and also the total days in a year (default is 261 days work). The remaining column will automatically display the calculation automatically using equation (1). The supplier order data is displayed on the right of the supplier orders tab.

\[ EOQ = Q^* = \left(\frac{2. D . S}{H}\right)^{1/2} \]  \hspace{1cm} (1)

where,
- \( Q^* \) = Economic Order Quantity (EOQ)
- \( D \) = Demand within 1 (one) year
- \( S \) = Ordering cost
- \( H \) = Holding cost

4.5.2. Customer Order. This tab is useful for inserting, editing, and deleting customer order data. In this tab, the user will be asked to enter the customer ID (selected via the dropdown list), items ordered by the customer (via the dropdown list), the annual demand, the price of the message, lead time, and also the total days in a year (default is 261 days work). The remaining column will automatically display the calculation automatically using equation (1). The customer order data is displayed on the right side of the customer orders tab.
4.6. Cross-dock data.
In this form, the user needs to press the "check" button so that the application can process all order data entered by the user and generate a "cross-dock checking" report. Column "Day" contains certain customers who will take goods from the warehouse, while the column "customer ID" contains ID from the customer. The column "item ID" contains ID of the item ordered by the customer, and column “cross-dock” contains the number of items that have cross-docked. The column "warehouse" contains the number of items taken from the warehouse, and the "out of stock" column contains the number of items that are less than the number requested by the customer.

4.7. Testing
Table 1 demonstrates the reliability testing of the DSS from the user side. This test discusses the use of each available menu. The testing stage is important to see the response of each menu function that is tailored to the original purpose. All scenarios on each menu match the expected results.

| Test Scenario       | No   | Test Case                                                                 | Expected Result                                                                 | Passed |
|---------------------|------|---------------------------------------------------------------------------|---------------------------------------------------------------------------------|--------|
| Inserting Supplier Data | TC_001 | User open the supplier data form, then input all the data and click save button | The data from user input is saved, and showed in supplier table                  | Yes    |
| Updating Supplier Data | TC_002 | User open the supplier data form, then input all the data and click update button | The specific data on database is updated as user input on supplier data form     | Yes    |
| Deleting Supplier Data | TC_003 | User open the supplier data form, then select the data that user want to delete. After that, click delete button | The selected data deleted from supplier table                                    | Yes    |
| Inserting Customer Data | TC_004 | User open the customer data form, then input all the data and click save button | The data from user input is saved, and showed in customer table                 | Yes    |
| Updating Customer Data | TC_005 | User open the customer data form, then input all the data and click update button | The specific data on database is updated as user input on customer data form     | Yes    |
| Deleting Customer Data | TC_006 | User open the customer data form, then select the data that user want to delete. After that, click delete button | The selected data deleted from customer table                                    | Yes    |
| Inserting Item Data | TC_007 | User open the item data form, then input all the data and click save button | The data from user input is saved, and showed in item table                      | Yes    |
| Updating Item Data | TC_008 | User open the item data form, then input all the data and click update button | The specific data on database is updated as user input on item data form         | Yes    |
| Deleting Item Data | TC_009 | User open the item data form, then select the data that user want to delete. After that, click delete button | The selected data deleted from item table                                        | Yes    |
| Inserting Supplier Order Data | TC_010 | User open the supplier order form, then input all the data and click save button | The data from user input is saved, and showed in supplier order table           | Yes    |
| Test Scenario          | No  | Test Case                                                                 | Expected Result                                                                 | Passed |
|-----------------------|-----|---------------------------------------------------------------------------|---------------------------------------------------------------------------------|--------|
| Updating Supplier     | TC_011 | User open the supplier order form, then input all the data and click update button | The specific data on database is updated as user input on supplier order form | Yes    |
| Deleting Supplier      | TC_012 | User open the supplier order form, then select the data that user want to delete. After that, click delete button | The selected data deleted from supplier order table | Yes    |
| Inserting Customer     | TC_013 | User open the customer order form, then input all the data and click save button | The data from user input is saved, and showed in customer order table | Yes    |
| Updating Customer      | TC_014 | User open the customer order form, then input all the data and click update button | The specific data on database is updated as user input on supplier order form | Yes    |
| Deleting Customer      | TC_015 | User open the customer order form, then select the data that user want to delete. After that, click delete button | The selected data deleted from customer order table | Yes    |
| Cross-dock Checking    | TC_016 | User open the cross-docking panel, click check button | The cross-dock checking data showed on cross-dock table | Yes    |

Future studies can discuss the layout [11] and warehouse capacity. The objective function can also be a reduction in costs and delivery times simultaneously [1]. The design of cross-docking facilities and truck scheduling is more practical for use in reverse logistics networks [15]. The assumption that there is an uncertainty in the arrival time of the trucks can be discussed [16,23]. The stochastic travel time may be considered as the unique characteristics [30]. This study still uses the deterministic EOQ equation, so that further research can discuss the application of probabilistic EOQ. Demand from retail and consumers is deterministic and shortages of goods are still acceptable under the backorder policy [6]. Since the work environment has a positive and significant effect of improving the work performance [31], hence the future study may lead to the work performance measurement while using the particular DSS.

5. Conclusion

This research can help companies in making decisions from an operational level. This research is also the first step in developing a decision-making model up to the tactical and strategic stages. As an illustration, the company can later manage the conditions of inventory and resources in the warehouse in serving suppliers and consumers.

The generated DSS from this study can accurately detect the time and quantity of certain goods that are cross-docked. If the quantity required by the consumer cannot be met by the warehouse, then the item is categorized as out of stock. By knowing the time and quantity of goods at the cross-dock, warehouse managers can make quick and precise decisions regarding the required resources such as the number of operators and forklifts.

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**Acknowledgment**

This work is supported by the Directorate of Research, Development and Community Service, Universitas Bunda Mulia. The authors also express gratitude to the research team which consists of Industrial Engineering, Informatics Engineering, and Information Systems colleagues for providing opportunities for growth through fresh and useful research activities.