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Research Article

Milk run strategy optimization with any logistix: Chemical product distribution in indonesia

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Abstract

Third-party logistics (3PL) providers worldwide have evolved due to logistics service outsourcing in recent years. Customer satisfaction and company reputation are greatly influenced by the operational performance of their third-party logistics (3PL). Third-party logistics companies usually focus on combining transportation and warehousing services. Specifically, this transportation service comes with substantial costs, typically accounting for one-third to two-thirds of total logistics operating costs; therefore, this study focuses on the optimization of transportation routes for the distribution of chemical products in the Jakarta Greater and Karawang areas using the Transportation Optimization (TO) module in anyLogistix software. This study uses an iterative analysis approach to pursuing a "maximum number of customers in one route" to find the optimal scenario regarding transportation costs and distance travelled. We want to improve route planning, reduce transportation costs, and increase the profit margin obtained through simulation and optimization. Four scenarios are generated with different maximum numbers of customers per route, ranging from 3 to 6. The results show that Scenario 3, with a maximum of 5 customers per route, produces the lowest total transportation cost of IDR36,113,000 and a total distance traveled of 12,235 km. Scenario 4, with six customers per route, increases transportation costs to IDR38,808,000 due to the increase in direct shipments due to distance constraints. We highlight the importance of balancing the number of direct shipments, customer grouping, and route optimization to achieve cost efficiency. A recommendation was given to consider using heterogeneous vehicles and sourcing policies involving additional facilities for further optimization. Additional simulations using the simulation module (SIM) in AnyLogistix are also provided to further investigate facility costs and transportation modes in more detail.

Keywords:
Logistix;
Milk run;
Product distribution;
Transportation cost;
Transportation optimization

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1. Introduction

In recent years, third-party logistics (3PL) services have grown at a level never before seen as logistics companies attempt to capitalize on more worldwide prospective customers due to the demand for global networks and advanced information technology. 3PL promotes innovation, market expansion, and corporate growth by enabling businesses to concentrate on their core skills. There are various 3PL options according to price, services offered, location, technology, quality, etc. A competitive 3PL company that can provide multiple advantages will certainly be more likely to be chosen; therefore, they need to investigate their main activities more, namely operations and transportation. However, transportation is considered a significant company driver between these two activities. Without the transportation process, the flow of goods will not reach the downstream of the supply chain according to the established plan. In this business context, transportation plays a role in moving goods from one location to another. In 3PL operations, the carrier is responsible for moving goods from the manufacturer to the warehouse or distribution center and finally to the hands of the end customer (Setiawati & Tenriajeng, 2021). Transportation costs are a significant component of a logistics company's operating costs, accounting for one-third to two-thirds of the total logistics operating costs (Jauhar, 2016). In 3PL companies, transportation costs are generally the most significant cost item, so reducing this cost is essential to maintaining the company's competitiveness. Infrastructure, facilities, fuel consumption, and labor costs also affect transportation costs (Elisabeth & Nurhayati, 2019).

In theory, logistics activities are classified as non-productive activities or can be said not to produce goods, but logistics can generate profit margins, where most of the revenue from logistics activities is obtained from transportation activities. One of the leading logistics conglomerates from Denmark operating in Indonesia is PT ABC, which has several subsidiaries in various markets such as shipping lines (ocean), third-party logistics (logistics and services), port terminals, stevedoring services, and maritime services. Based on the company's report, the revenue contribution according to the company's sector can be seen as follows.

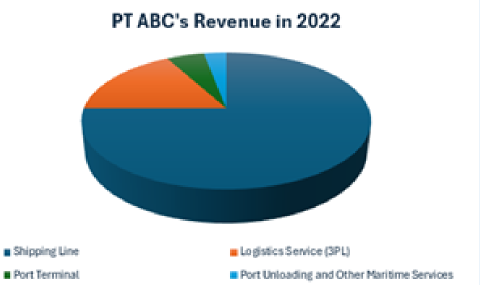

Fig. 1. PT ABC's revenue contributors in 2022

Figure 1 shows that companies in the Logistics & Services (3PL) sector are the second highest revenue contributors after companies in the shipping line sector, with revenue from shipping lines of USD 64.299 million, 3PL of USD 14.423 million, terminals of USD 4.371 million, and maritime tug-of-war services of USD 2.293 million. (PT ABC, 2023).

PT ABC has acquired a leading global 3PL company based in Shanghai, which was acquired globally in 2022. This acquisition also brings new customers to PT ABC worldwide, including in Indonesia, where they now serve 12 well-known clients.

To save on transportation operational costs, implementing the milk-run delivery system is a very effective alternative. The basic concept of Milk Run is a distribution system where the company will assign one vehicle in a certain period to distribute goods to several customers at once (multi-drop). This system can optimize distribution routes to reduce transportation costs, vehicle usage, and fuel consumption. (Brar & Saini, 2011). In addition to milk runs, there is also a direct delivery policy where the company will assign vehicles to distribute products directly to predetermined end customers. (Setiawan & Benedictus, 2021). Although previous studies have shown that direct delivery can help reduce transportation costs and increase the availability of storage space in the warehouse, the comparative results of this study show that the implementation of the Milk Run system has a better impact. (Setiani, Fiddieny, Setiawan, & Cahyanti, 2017).

Table 1.
Milk run app and direct delivery comparison

	Distance traveled (km) per 10 days	Total Delivery Time (hours)	Total Cost (Rp)
Milk Run	3625.2	6.05	50,917,200
Direct Delivery	3811.6	6.96	89,927,600

Product X, one of PT ABC's customers, stores and distributes finished chemical products (generally sanitation products) directly from the main Distribution Center (DC). This type of product is classified as slow-moving, and its demand is unpredictable because sanitation products are not seasonal.

Chemical products require exceptional safety, handling, and regulatory compliance considerations compared to regular consumer goods. Chemicals may trigger environmental or health issues, necessitating specific handling, storage, and transportation training. Prioritizing preventive measures while ensuring that personnel are adequately trained is the responsibility of the 3PL company. This product type also usually needs to be transported in particular packaging. Delivery of chemical items often requires distinctive techniques to stop leaks or reactions, whereas regular goods may employ conventional ones. Regular products can frequently be sent via ordinary logistics channels; however, transporting chemicals may require specialized trucks and routes, especially for hazardous commodities. Therefore, it is crucial to organize its distribution logistics rigidly.

The distribution of Product X products has implemented a milk run system, but shipping consolidation is still done manually based on distance assumptions. This is a gap for the author when proposing route optimization. The object of this research will use Product X's Accrual order data for May- June 2023.

Based on the explanation, this study will use the Transportation Optimization (TO) module in AnyLogistix software, where the route model entered into the software will be simulated and optimized based on data obtained from PT ABC. Optimization is carried out by considering demand, vehicle capacity, and time windows. TO analyzes shipments, rates, and other constraints to produce a realistic vehicle load plan, reducing overall transportation costs and achieving efficiency for the entire transportation network **(Logistics Management, 2016)**. The author hopes that by conducting this research, companies can be helped in making product delivery planning decisions, which can ultimately reduce transportation costs and increase company profit margins.

2. Research Methods

The methodology used in this study is the exact optimization method using the Transportation Optimization (TO)

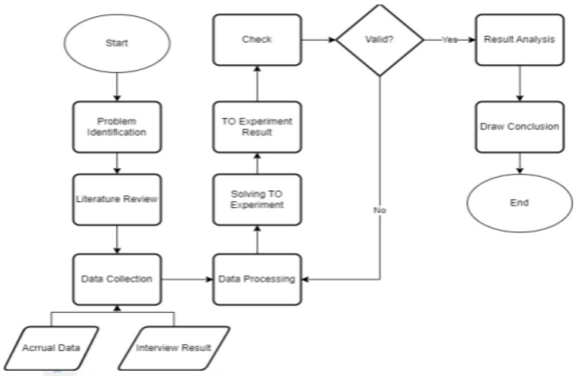

Fig. 2. Research flowchart

Problem identification occurs during the distribution process of finished chemical products, Product X, at the central DC. This stage aims to find the root of the problem that occurs in the distribution process of finished products, Product X. This process is carried out through direct interviews with related parties in the existing distribution process.

Following problem identification, a literature review is conducted to gather information from various sources to solve the problems found. At this stage, the study is conducted through journals and books to determine whether the model suits the research objectives. In this study, a critical review will be conducted in two stages. The first stage is collection and refinement using the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) method. In contrast, the second stage involves synthetic notes using the abstract, introduction, and conclusion (AIC) method. The stages in the flow diagram consist of the identification, screening, eligibility, and inclusion criteria stages. (Selçuk, 2019). This study's literature search was conducted using the Scopus database and additional sources such as Google Scholar or other citations. With the help of PRISMA, the methods and results of the systematic review can be reported in detail so that readers can assess the reliability and relevance of the review findings (Trifu, Smîdu, Badea, Bulboacă, & Haralambie, 2022). After completing the collection and refinement stage, the next stage is to record synthetic notes using AIC to compare previous studies and find research gaps for this study. This method is designed to help researchers and students perform quality fast skimming when reviewing several journals. In this method, more attention will be paid to the abstract, introduction, and conclusion sections of each article because, according to the inventor of this method, much information can be easily found in the abstract section. If detailed information is not listed in the abstract, the information can be easily found in the introduction and conclusion sections. (Pacheco-Vega, 2021).

An article by (Schubert, Kuhn, & Holzapfel, 2021) Presented a modeling approach and solution for integrated order picking and vehicle routing problems in the context of same-day delivery for omnichannel retailers in Europe. They used a heuristic method to build an initial solution that involves solving the order-picking problem and the vehicle routing problem separately. Then, the Generalized Variable Neighborhood Search (GVNS) algorithm is applied to obtain an integrated solution. They suggest using deterministic demand data so that the solution is more realistic and assumes that vehicles are always available so that it is easy to get a good level of service.

Another article (Wei & Zhou, 2014) A simulated annealing algorithm with memory was proposed to solve the vehicle routing problem with a time window. The algorithm combined the advantages of genetic algorithm and simulated annealing to increase efficiency. Their results showed that the algorithm effectively solved the problem with a shorter running time and stronger practicability.

(Wijanarko & Sepadyati, 2022) Optimizing distribution routes by minimizing costs is an essential method for increasing company efficiency. They studied the optimization of the distribution process under the capacitated vehicle routing problem with the time window model at the most significant private gas company in Indonesia using AnyLogistix software with the Transportation Optimization module feature. The results show more than a 20% reduction in travel distance gained.

Further, another article (Kurniawan, Mustafa, & Redi, 2023) provided the research with a focus on transportation optimization with capacitated vehicle routing problem. They brought a case study of the Gaslink CNG C-CYL product using AnyLogistix software. They demonstrated that AnyLogistix can optimize transportation to minimize route distance and distribution costs. However, there is a limitation on the number of demand points used there; hence, there is a need for large-scale experiments as studied in this paper.

In conclusion, solving the Vehicle Routing Problem (VRP) with simulation-based methods, especially with AnyLogistix software, is still relatively rare compared to heuristics. Most existing research still relies on heuristic solution approaches, which can be effective but often fail to account for the changing conditions in logistics operations. AnyLogistix can model real-world dynamic time factors as a period to be simulated in the optimization process, allowing for the incorporation of changing conditions over time and creating a more realistic representation of actual operations. (Chidozie, Ramos, Vasconcelos, & Ferreira, 2024). Second, there is still little previous research that uses deterministic demand that can be improved hence, the simulation results produce a more stable and reliable output than stochastic simulations. (Wang, 2023). Other than that, no research has been aimed at finding the maximum number of customers or demand points that can be served in one route under the capacitated vehicle routing problem with the time window (CVRPTW) model. In contrast, one of many aspects that can be explored more with comprehensive simulation-based optimization ability is the effect of a maximum number of customers in one route on the overall distribution performance. (Cueto, Gjeroska, Vilalta, & Anjos, 2021). Therefore, our study intends to close this gap with the assumption that the number of vehicles can be adjusted to meet targeted customer satisfaction.

Data collection is the stage where the author collects all the data that will be the subject of research. Data sources are divided into two: Accrual Data All Order Product X 2023 obtained from the Oracle Transportation Management (OTM) system of PT ABC and direct interviews with related parties.

All data from the previous stage will be processed into Excel using the TO scenario template in AnyLogistix. It is important to ensure that all data has been entered correctly and has the appropriate index. This process is also closely related to the CVRPTW, a subset of the vehicle routing problem (VRP), categorized as an NP-hard problem. CVRPTW restricts each point's vehicle capacity and time windows (start and end times). In CVRPTW, vehicles must depart and return to the same depot. (Dornemann, 2023). CVRPTW only allows vehicles to deliver goods to a point if the vehicle capacity is sufficient to meet the demand at that point and the vehicle can reach the point within the specified time window. If the vehicle arrives before the start time, then the vehicle must wait until the start time. If the vehicle arrives after the end time, then the vehicle must return to the previous point or to the depot.

Once aligned with the AnyLogistix Excel template format, the scenarios will be imported into the AnyLogistix software. By definition, transportation optimization is the process of analyzing shipments, rates, and constraints to produce realistic vehicle load plans, reduce total transportation expenditures, and achieve efficiencies across the transportation network. (Logistics Management, 2016). However, AnyLogistix has a TO feature where the TO module can determine the sequence of loading and unloading points and create a round-trip trip plan, known as a "milk run." This experiment will generate a route plan and provide the distance and cost of travel between these points. (Wilkinson, 2017). Milk run can help reduce shipping costs by reducing empty trips and the number of vehicles required. In its solution, TO in AnyLogistix will solve the routing problem by considering the road network or distance between existing points. (AnyLogistix, 2019; Ivanov, 2021).

The TO module is designed to optimize transportation routes by analyzing shipments, rates, and constraints to produce realistic vehicle load plans with the goal of reducing total transportation expenditure and achieving efficiencies across the transportation network (Logistics Management, 2016). TO module can accommodate several distribution considerations in one scenario, such as:

- Types of vehicles and their capacities: The TO module allows users to define different vehicle types, each with specific capacities and speed limits. For example, in the case study by (Sepadyati, Prayogo, Ulin, Chandra, & Frederika, 2024), the Distribution Center used various truck types each with different capacities. This ensures that the optimization process considers the physical constraints of the vehicles used in the distribution network.
- Time windows on customers: The module supports time window constraints, ensuring deliveries are made within the specified service periods. In the (Sepadyati, Prayogo, Ulin, Chandra, & Frederika, 2024) In the study, deliveries were constrained to occur between 8:00 AM and 5:00 PM, which aligned with the operational hours of both the distribution center and the customers. This is particularly useful for industries where timely delivery is critical, such as in the fast-moving consumer goods (FMCG) sector. (Wijanarko & Sepadyati, 2022).
- Earliest Shipping Time at logistics facilities: Users can set the earliest time at which shipments can depart from logistics facilities, ensuring that the optimization aligns with operational schedules (AnyLogistix, 2019). For instance, in the study case, shipments were assumed to depart simultaneously at 8:00 AM, which helped streamline the scheduling process and reduce delays (Sepadyati, Prayogo, Ulin, Chandra, & Frederika, 2024).
- Full truck load coefficient: The TO module can enforce a minimum load ratio for direct shipments, ensuring that vehicles are utilized efficiently and reducing the number of partially loaded trips. In the study by Sepadyati et al. (2024), the module was configured to ensure truck utilization exceeded 70%, resulting in significant cost savings and reduced empty trips.

Apart from these, some parameters must be set in the TO experiment settings, including:

- Max number of customers on a route: This constraint limits the number of customer stops a vehicle can make on a single route, which helps manage driver fatigue and delivery schedules

(Wijanarko & Sepadyati, 2022). In the case study, the TO module consolidated deliveries to multiple customers on a single trip (multidrop), reducing the total number of trips required.

- Max segment length between objects: This parameter restricts the maximum distance between two consecutive stops on a route, ensuring that the optimization does not produce impractical or overly long routes (AnyLogistix, 2019). For example, in the (Sepadyati, Prayogo, Ulin, Chandra, & Frederika, 2024) In the study, the maximum segment length was set to 900 km, ensuring that routes remained feasible given the distribution center's operational constraints.

Despite its robust features, the TO module has certain limitations:

- Real-time variability: The module relies on predefined road networks and does not account for real-time traffic conditions, road closures, or weather disruptions, affecting delivery times and routes. For example, in the Surabaya Distribution Center case, the TO module produced routes that were slightly shorter than those generated by Google Maps, with differences ranging from 9.81 km to 21 km. These discrepancies were attributed to the module's inability to account for real-time road conditions (Sepadyati, Prayogo, Ulin, Chandra, & Frederika, 2024).
- Data requirements: The TO module requires accurate and comprehensive data inputs, including customer locations, demand volumes, vehicle capacities, and time windows. Inaccurate or incomplete data can lead to suboptimal route plans and reduced efficiency.

Despite these limitations, the TO module in AnyLogistix provides a robust framework for optimizing transportation networks, particularly in scenarios involving capacitated vehicles and time windows. It also enables optimization modeling based on real-world study case constraints.

Eleven table features used in the model will be rechecked: "Customer," " DC and Plant," "Demand," "Group," "Location," "Line," "Period," "Product," "Source," "Time Window," and "Vehicle Type." Then, optimization will be run with parameter settings adjusted for each scenario.

The optimization results will be the number of routes, total transportation costs, and total distance traveled from the route optimization results.

Next, the results of the TO experiment will be checked to see if the results appear or not. If they do not occur, the data processing process will be repeated to check the suitability of the data details. If they appear, the results will be checked to determine whether they are valid and whether the model created is by the original purpose of its creation. If not, the process will be adjusted to the TO Experiment Completion stage. If it is correct, the next stage can be continued.

At the result analysis stage, various information from the optimization results can be presented and explained thoroughly. Detailed information can also be conveyed so that the research results are well received.

The conclusions will answer the research objectives and the results obtained after the research. It is hoped that the suggestions given can be used as consideration for further research and for the company.

3. Results and Discussion

This chapter discusses the research results, starting with the data collection process and ending with the experimental analysis of the data. The results of this study will be used to draw conclusions related to the research objectives that have been set.

3.1. Data Collection

To conduct data analysis, data collection is required first to meet the simulation needs. The data required in this study is the Accrual All Order Product X data for May to July 2023, which contains customer demand location points in Jabodetabek and Karawang, historical demand data, and the types of trucks used. In addition, transportation cost data and several other primary data related to truck details are also needed. The data collection stage was carried out through an official request to the Transportation Division of PT ABC. Furthermore, interviews were also conducted with shipping planning staff regarding the time window and truck capacity assumptions.

Location Data

Location data consists of information about the location of the Main Distribution Center (DC) where the Product X product is stored and distributed. In addition, there is location data on the customer demand points of Product X in the Jabodetabek and Karawang areas.

Table 2
Summary of DC location

Site Name	Latitude	Longitude
Main DC	-6.20168	106.96766

Here is an example of customer location data for visualization purposes:

Table 3
Customer locations

Customer Name	*Latitude*	*Longitude*
Customer 1	-6.34645	107.14732
Customer 2	-6.37453	106.91732
Customer 3	-6.31427	106.98741
Customer 4	-6.19142	106.97786
Customer 5	-6.31103	107.14535
Customer 6	-6.26839	107.04097
Customer 7	-6.29153	107.10108
Customer 8	-6.38718	107.16224
Customer 9	-6.2851	107.12702
Customer 10	-6.22782	107.00435

Then, after interviewing with the company mentor, I learned that the current XYZ product distribution planning system is still based on the assumption of a manual planner. If there is more than one customer point close to the exact delivery time, a milk run will be carried out without considering the distance afterward. After that, it is continued by ordering a truck to the outsourcing vendor according to the policy stated in the contract that has been made.

Historical Request Data

The following is historical demand data taken from the Accrual All Order data for Product X from May 2023 to July 2023, with the aim of obtaining medium—to long-term simulation data. It is an example of historical customer demand data for visualization purposes.

Table 4
Historical demand

Customer Name	Order Date	Order Quantity (kg)
Customer 1	5/31/2023	208.5
	7/20/2023	208.5
Customer 2	5/3/2023	25.4
	5/15/2023	90.8
	5/26/2023	341.179992
	6/14/2023	11.2
	7/5/2023	208.84
	7/20/2023	62.7
	7/31/2023	43.4
Customer 3	5/4/2023	1328.760015
	6/6/2023	2493.060024
	6/23/2023	200
	6/26/2023	1099.069996
	7/6/2023	1506.80001
	7/7/2023	585.2
Customer 4	5/25/2023	1951.590024
	5/27/2023	762.7
Customer 5	5/26/2023	493.499996
	6/8/2023	313

Transportation Cost Data

In this study, an L300 truck is assumed to be the transportation used, as this type of truck was the most frequently used during the three months of Accrual data from May to June 2023. Because truck delivery at PT ABC uses an outsourcing vendor, there is a fixed cost for using the L300 truck, which is IDR 539,000 per truck (on-call cost).

Data TO AnyLogistix

In AnyLogistix software, several features (tables) can be filled in according to the needs and objectives of the experiment. In this study, the AnyLogistix Transportation Optimization (TO) features that will be used consist of 11 features, namely "Customer," " DC and Plant," "Request," "Group," "Location," "Route," "Period," "Product," "Source," "Time Window," and "Vehicle Type." This data dramatically affects the results of the experiment to be conducted.

3.2. Data processing

Transportation Optimization Design

After entering all the demand data for 292 Product X customers in the Jabodetabek and Karawang areas and deciding on one main source, the main DC, the supply chain network visualization was carried out. This visualization shows the red logo as the DC and the blue logo as the customer, where both are interconnected, which means the supply chain model is integrated.

Fig. 3. Supply chain network validation in AnyLogistix.

Furthermore, the Geographic Information System (GIS) map view in AnyLogistix software validates the model by displaying a visual route, as shown in Figure 4.

Fig. 4. GIS road network visualization in AnyLogistix

Before the TO experiment is run in AnyLogistix software, several experimental parameters need to be set first, namely the start and end dates of the simulation, the maximum number of customers that can be served in one route or one delivery, the type of vehicle to be considered in the simulation, and the travel distance limit between points. In this study, all scenarios use the same design except for the "Sourcing" feature and several parameters that will be changed to find the most optimal transportation optimization scenario.

The duration of the experiment is 2 months, namely from January 10 to March 10, 2023. The type of vehicle used in this experiment is an L300-type truck. Then, the travel segment limit is the maximum distance from the DC to the customer, and if the distance exceeds the limit, the route will be limited. In this experiment, the travel segment limit is set at 100 km, assuming this distance represents the distance from the two endpoints of the experimental area boundary, namely Tangerang and Karawang. There is also a return segment limit, the maximum distance from the last customer returning to the DC location, which is 70 km. This assumption is based on the furthest distance from the DC to the furthest point in the simulation, namely Tangerang. The PT ABC transportation division team has validated the travel segment limit and return segment settings before being implemented in AnyLogistix.

After conducting several scenario experiments with iterative analysis method to find the optimal scenario, it was found that there were four scenarios in the implementation of this research, where the data entered into the model was the same, except for the parameter "maximum customers in one route."

1. Scenario 1

In scenario 1, the experiment was conducted with the maximum customer parameters in one route set for three customers. The AnyLogistix TO results showed that L300-type vehicles traveled 98 routes, with a total transportation cost of IDR 52,822,000 and a total distance traveled of 13,204 km.

2. Scenario 2

In scenario 2, the experiment was conducted with the maximum customer parameters in one route set for four customers, so that the TO AnyLogistix results showed that there were 88 routes traveled by L300 type vehicles with a total transportation cost of IDR 47,432,000 and a total distance traveled of 12,985 km.

3. Scenario 3

In scenario 3, the experiment was conducted with the maximum customer parameters in one route set for five customers. The results of TO AnyLogistix showed that there were 67 routes traveled by L300-type vehicles with a total transportation cost of Rp 36,113,000 and a total distance of 12,235 km.

4. Scenario 4

In scenario 4, the experiment was conducted with the maximum customer parameters in one route set for six customers. The results of TO AnyLogistix showed that there were 72 routes traveled by L300-type vehicles with a total transportation cost of Rp 38,808,000 and a total distance of 11,918 km.

From the results of scenarios 1 to 4, changes in the maximum number of customers in one route significantly influence finding the optimal distribution scenario. Based on the results obtained, the more customers that can be served in one route, the lower the transportation costs, number of routes, and total distance traveled, as long as the solution found is optimal.

Comparison of Shipping Method Frequency Between Scenarios

As explained in the previous chapter, the component of the shipping method (direct shipment/ or milk run shipment) in the distribution network directly impacts the logistics distribution cost. Therefore, it is essential to carefully analyze the frequency of shipping methods among the scenarios shown in the following figure. This in-depth analysis is necessary to understand the total transportation cost comprehensively.

This analysis allows for a more detailed comparison of how different delivery methods, both direct delivery and milk run, impact distribution costs and operational efficiency.

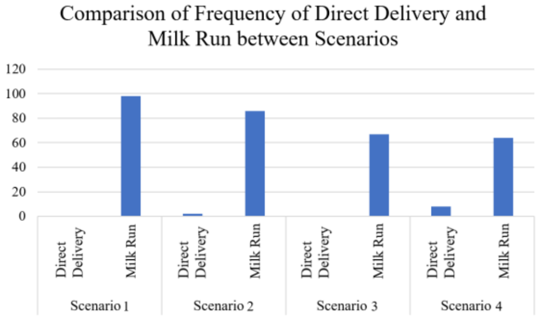

Fig. 5. Comparison of direct delivery and milk run frequency across scenarios

Figure 5 shows variations in the number of direct delivery and milk run routes across different scenarios, influenced by constraints such as trip segment limits, vehicle capacity, and time windows. Scenario 1 consists solely of 98 milk run delivery routes, while scenario 2 includes two direct deliveries and 86 milk run (88 total routes). Scenario 3 relies entirely on 67 milk run routes, whereas scenario 4 features eight direct delivery and 64 milk run routes. Simulation constraints, such as trip and return segment limitations, primarily drive direct deliveries. When a request point exceeds the feasible geographical distance, it is processed as a direct delivery instead of consolidated with other trips. Factors like insufficient vehicle capacity and time window restrictions influence the delivery route selection. These complexities highlight the challenges of optimizing delivery routes under predefined constraints.

Comparison of Transportation Costs Between Scenarios

To visualize the results of this study, it is necessary to compare the transportation costs between scenarios to find the most optimal scenario where the number of routes and transportation costs are important considerations. The results of the cost comparison are as follows:

In this comparison, we will see how each scenario affects the total transportation cost based on the number of routes, shipping methods, and other variables that affect overall distribution efficiency. Determining the optimal scenario will help reduce costs while maintaining operational efficiency.

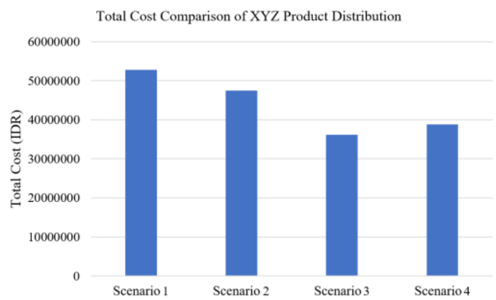

Fig. 6. Comparison of total distribution costs across different scenarios

Figure 6 shows that the scenario with a maximum of 5 customers per route stands out as the most optimal choice compared to the other scenarios. This observation is valid because the reduction in the number of routes indicates a more efficient distribution network, directly impacting the total transportation cost reduction. Conversely, increasing the maximum number of customers per route to 6 in scenario four leads to higher costs, likely due to increased operational constraints.

Based on the previous analysis, adding one customer in scenario 4 disrupts the clustering of customer distribution networks, leading to an increase in direct deliveries. As already established, the number of direct deliveries in scenario four significantly increases the total transportation cost. While reducing the total distance traveled and the number of trips generally leads to cost savings, scenario four demonstrates that this is not always the case. The increased number of direct deliveries results in more delivery routes, up by 7.46% compared to scenario 3. This leads to more significant fixed costs in the transportation optimization module. The fixed costs can be reflected as vehicle deployment fees and driver wages in real-world cases. This highlights a crucial trade-off that although fewer trips and shorter distances can improve efficiency, an excessive increase in direct deliveries disrupts cost savings by underutilizing vehicle capacity and increasing per-route operational expenses.

Based on these findings, PT ABC cannot solely rely on the basic theory that maximizing customers per route leads to a more cost-efficient distribution system. Instead, the balance between customer clustering, route consolidation, and cost-effective vehicle utilization must be carefully considered to optimize overall logistics performance.

4. Conclusion

Based on the optimization and analysis results, it can be concluded that this study produces a route design in the Transportation Optimization module in AnyLogistix through an iterative analysis method that makes four different scenarios for the use of L300-type trucks. The data used for the features in the Transportation Optimization (TO) before has been confirmed for validity by the transportation division of PT ABC so that the simulation results can adequately represent the existing model. In each scenario, the "maximum customers in one route" parameter is tested to find the maximum number of customers that can be served in one route optimally.

The results of each scenario are different and influenced by the limitations set as TO parameters, such as distance limitations and the maximum number of customers in one route. In each scenario, the maximum number of customers in one route is tested by iterative analysis by adding one customer, starting from scenario 1 with a maximum of 3 customers per route. The total transportation cost in Scenario 1 is IDR 52,822,000; in Scenario 2, it is IDR 47,432,000; in Scenario 3, IDR 36,113,000; and in Scenario 4, IDR 38,808,000. Therefore, it can be concluded from the experimental results that scenario 3 has the most optimal total cost with a maximum number of customers in one route of 5 customers. If increased to 6 customers, as in scenario 4, the transportation cost will increase again due to distance limitations, so the number of routes increases.

In addition, the delicate balance between the number of direct shipments, customer grouping, and route optimization becomes apparent. As shown in scenario 4, even a slight change in customer grouping, such as adding one customer to a route, can disrupt the entire distribution network, increasing direct shipments and transportation costs. For practical application, PT ABC can improve truck utilization by limiting routes to five customers based on scenario four findings. This strategy may enhance distribution efficiency and reduce operational costs.

Future research could extend TO results into a simulation module (SIM) using AnyLogistix to optimize distribution through a milk run table, considering facility costs and heterogeneous vehicle selection. Incorporating overflow goods from other warehouses could also refine sourcing policies.

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