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Determination of product distribution strategy with direct shipping and cross-docking methods

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ABSTRACT

The right product distribution strategy is a decision that must be considered by the company to increase optimal profits, because an effective and efficient strategy can reduce distribution costs. A tire manufacturing company experiences difficulties in choosing the right product distribution strategy, because shipping costs are always increasing. For this reason, research was conducted in order to be able to provide optimal strategy proposals to be implemented in the company. From the results of the research and data processing carried out, there are two tests for the direct delivery strategy and the warehouse delivery strategy. The research described in the given statement contributes to the field of product distribution strategy, specifically in the context of a tire manufacturing company facing increasing shipping costs. Testing of these strategies is carried out using the Vehicle Routing Problem (VRP) method to calculate the total optimal distribution cost of each strategy. The mathematical model in this study was solved using optimization software. Based on the research results, the delivery strategy through the warehouse is better than the direct delivery strategy and the cross-docking strategy with a total cost of Rp. 3,213,200. This result is smaller than the cross-docking of IDR 3,544,000 each. This shows that the warehouse delivery strategy can save costs by 8.86%. The research concludes that the warehouse delivery strategy offers the most favorable results in terms of cost savings and efficiency compared to the direct delivery and cross-docking strategies.

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1. INTRODUCTION

Product distribution planning is a crucial aspect for the company. An efficient and timely distribution process can help build customer trust and reduce costs associated with distribution activities (Kłodawski et al., 2017; Zhou et al., 2018). The most effective distribution will facilitate the flow or access of goods by consumers so that they can easily obtain them (Jason et al., 2022). Additionally, consumers will receive goods according to their needs (Ayu Muchlisa & Surianto, 2021; Perdomo et al., 2021) .

In general, there are three product distribution strategies. The first strategy is direct shipping. In this strategy, product delivery is carried out directly from the factory to the customer (Nikolopoulou et al., 2017). This strategy is suitable for use when the type of product being distributed is a perishable product, such as food ingredients, etc. This strategy can also reduce storage costs because there are no intermediaries between factories and customers (Liu et al., 2021). However, this strategy tends to generate relatively large transportation costs.

The second strategy is delivery through the warehouse. In contrast to the direct shipping method, this strategy is suitable for products with high demand uncertainty and relatively long shelf life. In the delivery strategy through the warehouse (warehouse shipping), products will be distributed first to the warehouse or distribution center and then distributed to customers (Pujawan & Mahendrawathi, 2017).

The last strategy is the cross-docking strategy. In this strategy, products will flow through the cross-dock facility between the factory and the customer(Ahkamiraad & Wang, 2018). In this place the sender will meet and load transfer occurs (Dondo et al., 2011). Activities that occur are receiving, sorting and loading. In general, the advantage of this strategy is that delivery can be relatively fast and can still achieve a good level of transportation economy due to consolidation (Pujawan & Mahendrawathi, 2017).

This study aims to analyze the level of efficiency of the distribution strategy implemented by PT XYZ, namely direct shipping and cross-docking. The shortest routes/path problem is commonly encountered in practical situations as many real-life problems involve the transportation of goods between two specific nodes in a network with the objective of minimizing costs (Sanjaya et al., 2019). Optimal distribution routes/path and total distribution costs will be compared for each strategy. This research is limited to the distribution area in North Sumatra.

The assumptions used include calculating the distance between locations using the distance between coordinates method, a fixed fuel cost of IDR 18,000 per liter, fuel consumption for transportation modes of 10 km per liter, and the identity of the mode of transportation at each facility. The results of this study are expected to provide insight and input for PT XYZ in improving the performance of their product distribution. In addition, this research is also useful as a contribution to educational institutions and subsequent researchers in the field of product distribution.

2. RESEARCH METHOD

This research itself is a type of comparative research. This study compares the two strategies and then provides conclusions on the comparative analysis of the two strategies(Li et al., 2019). The research was carried out at PT XYZ in the city of Medan, with the research object being product distribution strategies and product delivery strategies. The stages (process) of the research are described in the form of a flowchart in Figure 1.

In this research, data collection methodes were accessing from company records, surveys (interviews), analyzing existing data sets, and utilizing publicly available information. Furthermore, this researchers analyzed the calculated costs and compared them across the different strategies (direct shipping and cross-docking) using VRP methode and Lingo 19.0 . They would have evaluated the cost savings achieved by the warehouse delivery strategy in comparison to the other strategies.

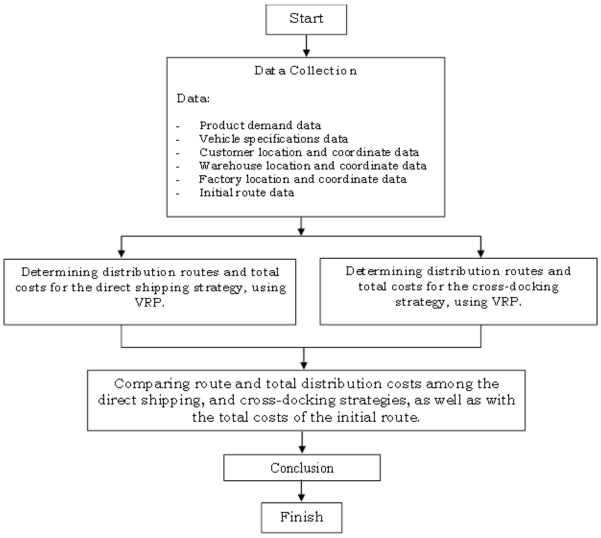

Figure 1. Research flowchart.

3. RESULTS AND DISCUSSIONS

This research began with data collection, the results of this activity were the company's initial route data. Initial route data in this study were collected in order to compare the initial distribution route planning with the optimal distribution route(Zheng et al., 2021). The initial distribution routes in this study were collected based on the two distribution methods currently implemented by the company, namely the direct shipping method. The initial route data can be seen in Table 1 below.

Table 1. Initial route data

Distribution Strategy	Distribution Route	Distribution Location	Number of Products	Distance (km)
Direct Shipping	1-2-1	Pbk - Mdn - Pbk	1185	10
	1-3-1	Pbk - Tj. morawa - Pbk	857	34
	1-4-1	Pbk - Stabat – Pbk	756	48
	1-5-1	Pbk - Binjai - Pbk	951	36
	1-7-1	Pbk - High cliff - Pbk	924	130
	1-8-10-1	Pbk - Kabanjahe - Siantar – Pbk	518	217
	1-6-1	Pbk - Sidikalang - Pbk	528	214
	1-11-9-1	Pbk - Sei rampah - Tj. balai - Pbk	847	296

The next step is to calculate the total distribution costs. The total cost of distribution in this study is calculated to assess the efficiency of each distribution strategy, direct shipping strategy and cross-docking strategy. In its calculations, the VRP method is used to determine the optimal distribution route, of course by complying with existing limitations, such as truck load capacity, etc. The VRP method will determine how much the minimum distribution costs will be incurred by each strategy. The mathematical model used for each strategy is solved using optimization software, Lingo 19.0. following discussion:

VRP Mathematical Model for Direct Shipping Strategy. In the direct shipping strategy, all products produced by the factory will be distributed directly to the customer's location. Therefore, this factory location is used as the starting location and ending location for each mode of transportation. The notation used is as follows.

The design of this mathematical model code in the Lingo 19.0 software can be seen in Figure 2.

```
MIN = @SUM( NXN: DIST * X)*FC + @SUM( NXN(I,J)|I #EQ# 1: X(I,J))*TC;

@FOR( N( K)| K #GT# 1:
  X( K, K) = 0;

  @SUM( N( I)| I #NE# K #AND# ( I #EQ# 1 #OR#
   Q( I) + Q( K) #LE# VCAP): X( I, K)) = 1;

  @SUM( N( J)| J #NE# K #AND# ( J #EQ# 1 #OR#
   Q( J) + Q( K) #LE# VCAP): X( K, J)) = 1;

  @BND( Q( K), U( K), VCAP);

  @FOR( N( I)| I #NE# K #AND# I #NE# 1:
   U( K) >= U( I) + Q( K) - VCAP + VCAP *
    ( X( K, I) + X( I, K)) - ( Q( K) + Q( I))
     * X( K, I);
  );

  U( K) <= VCAP - ( VCAP - Q( K)) * X( 1, K);

  U( K)>= Q( K)+ @SUM( N( I)|
   I #GT# 1: Q( I) * X( I, K));
);

@FOR( NXN: @BIN( X));

VEHCLF = @SUM( N( I)| I #GT# 1: Q( I))/ VCAP;
VEHCLR = VEHCLF + 1.999 -
 @WRAP( VEHCLF - .001, 1);

@SUM( N( J)| J #GT# 1: X( 1, J)) >= VEHCLR;
END
```

Figure 2b. Mathematical Model Code (Direct Shipping)

The distribution route for this strategy is determined using the VRP method. The results of this VRP method are the optimal results obtained through the Lingo 19.0 optimization software. The output results for direct shipping can be seen in Table 2.

Table 2. Optimal Distribution Route Results for Direct Shipping and Cross Docking Strategies

Initial/ Optimal	route	Optimal Route Distribution Locations	Number of Products	Distance (km)	Total cost
Optimal (Direct shipping)	1-2-1	Pbk - Mdn - Pbk	1185	10	IDR 3,525,600
	1-3-1	Pbk - Tj. morawa – Pbk	857	34	
	1-4-1	Pbk - Stabat – Pbk	756	48	
	1-5-1	Pbk - Binjai - Pbk	951	36	
	1-7-1	Pbk - High cliff - Pbk	924	130	
	1-8-6-1	Pbk - Kabanjahe - Sidikalang – Pbk	783	215	
	1-11-9-10-1	Pbk - Sei rampah - Tj. balai - Siantar - Pbk	1110	319	
Beginning (Direct Shipping)	1-2-1	Pbk - Mdn - Pbk	1185	10	IDR 4,173,000
	1-3-1	Pbk - Tj. morawa – Pbk	857	34	
	1-4-1	Pbk - Stabat – Pbk	756	48	
	1-5-1	Pbk - Binjai - Pbk	951	36	
	1-7-1	Pbk - High cliff - Pbk	924	130	
	1-7-1	Pbk - High cliff - Pbk	924	130	
	1-8-10-1	Pbk - Kabanjahe - Siantar – Pbk	518	217	
	1-6-1	Pbk - Sidikalang - Pbk	528	214	
Cross-docking route (third party)	1-0-1	Wrh - Pbk – Wrh	3500	40	IDR 3,544,000
	1-0-1	Wrh - Pbk – Wrh	3066	40	

In Table 2, it can be seen that the total cost that must be incurred if using the direct shipping strategy is IDR 3,525,600. The table also shows that there were 7 shipments with 7 different trucks. The number of products sent by each truck is below the truck's maximum capacity, which is 1200 units of product. In addition, the distance from each distribution route is also displayed with the longest route reaching 319 km. This optimal distribution cost is lower than the initial route distribution cost which must cost IDR 4,173,000. The biggest difference is in the number of delivery routes, where in the initial route there are 8 shipments, whereas in the optimal route it only takes 7 shipments to fulfill all requests.

VRP Mathematical Model for Cross-docking Strategy. In the cross-docking strategy, the products produced will be sent directly to the transfer location (Cross-docking) and then sent to the customer. In contrast to the warehouse shipping strategy, the cross-docking strategy uses certain public locations for the process of transferring goods, which is different from warehouse shipping which uses private company warehouses. With this, companies can save on storage and warehouse usage costs. In this strategy, the costs that must be incurred are the cost of using cross-docking services and transportation costs from the factory to the transfer location. In this study, it is assumed that the warehouse location is a transfer location (cross-docking) and the cost of using the cross-docking is IDR 1,200.

The design of the mathematical model code for the cross-docking strategy in Lingo 19.0 software can be seen in Figure 3.

```
MIN = CD*@ROUNDUP(@SUM(N(I): Q(I))/VCAP,0) + VEHCLR*TC
      + DISTPC*2*VEHCLR*FC;

@FOR( N( K)| K #GT# 1:
  X( K, K) = 0;

  @SUM( N( I)| I #NE# K #AND# ( I #EQ# 1 #OR#
   Q( I) + Q( K) #LE# VCAP): X( I, K)) = 1;

  @SUM( N( J)| J #NE# K #AND# ( J #EQ# 1 #OR#
   Q( J) + Q( K) #LE# VCAP): X( K, J)) = 1;

  @BND( Q( K), U( K), VCAP);

  @FOR( N( I)| I #NE# K #AND# I #NE# 1:
   U( K) >= U( I) + Q( K) - VCAP + VCAP *
    ( X( K, I) + X( I, K)) - ( Q( K) + Q( I))
     * X( K, I);
  );

  U( K) <= VCAP - ( VCAP - Q( K)) * X( 1, K);

  U( K)>= Q( K)+ @SUM( N( I)|
   I #GT# 1: Q( I) * X( I, K));
);

@FOR( NXN: @BIN( X));

VEHCLF = @SUM( N( I)| I #GT# 1: Q( I))/ VCAP;
VEHCLR = VEHCLF + 1.999 -
 @WRAP( VEHCLF - .001, 1);

@SUM( N( J)| J #GT# 1: X( 1, J)) >= VEHCLR;
END
```

Figure 3. Mathematical Model Code (Cross-docking)

The results of calculating the total cost of the cross-docking strategy can be seen in Table 2. The total cost that must be spent on the cross-docking strategy is Rp. 3,544,000.-. Where the largest portion is found in the cost of using cross-docking. In the direct shipping strategy, the absence of shipping and storage in the warehouse reduces one-way costs. However, in the problem in this study, the small capacity of the trucks causes these costs to be large so that the warehouse strategy is better. In terms of distribution distance, the longest route reaches 319 km. The distribution route in this strategy is relatively longer compared to the direct shipping strategy due to the location where the demand for products served is also greater and the truck capacity is larger.

In the final stage of this research, a sensitivity analysis was carried out to determine the effect of changes in parameter values on the optimization results, namely the sensitivity analysis of truck capacity. In the truck capacity sensitivity analysis, the value of the capacity of each truck will be changed. Changes in this value are made within the range of ±10%, where at 0%, the capacity of each truck does not change, which is 1200 product units for factory trucks and 3500 units for warehouse trucks. Based on the changes in the capacity value, the results of changes in the total distribution costs are obtained as shown in Figure 5 below.

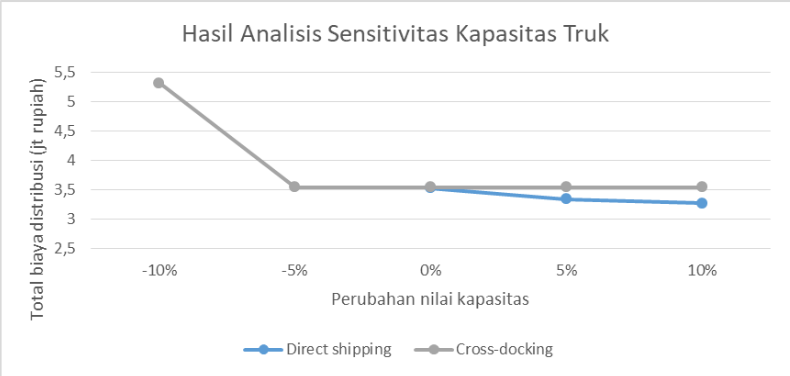

Figure 4. The results of the truck capacity sensitivity analysis

On the direct shipping strategy graph, the value of distribution costs at -5% and -10% positions cannot be determined. This was caused by the number of requests that exceeded the load capacity of the trucks. Therefore, the load capacity of the factory truck cannot be less than 5% of the value. Based on the results of the above analysis, it can be suggested for the company to choose a truck with a larger capacity regardless of the increase in shipping costs, security, etc.

The results of this sensitivity analysis show that the direct shipping strategy is still superior regardless of changes in shipping costs. As input for the company, regardless of the dynamics of shipping costs and fuel costs, the use of trucks with large capacities will benefit the direct shipping strategy and the warehouse shipping strategy.

4. CONCLUSION

In this research, a mathematical model was designed for direct shipping strategy, warehouse shipping strategy and cross-docking to assess how efficient the three strategies are based on existing data. Based on the analysis using the vehicle routing problem (VRP) method, the optimal distribution cost for the direct shipping strategy is IDR 3,525,600 with the longest route of 319 km. Meanwhile, for the cross-docking strategy, a fee of IDR 3,544,000 is required. For the total number of shipments, the direct shipping strategy requires 7 shipments to meet customer demand. Meanwhile, the cross-docking strategy requires 2 shipments from the factory to the cross-docking location. From the results above, it can be concluded that the direct shipping strategy is better than the cross-docking strategy in terms of costs. The implication of this research was to provides valuable insights into the cost efficiency of different distribution strategies. By quantifying the optimal distribution costs for each strategy, the study highlights the potential cost savings that can be achieved by implementing the direct shipping strategy compared to the cross-docking strategy. This information can guide decision-making processes in the tire manufacturing company and potentially other companies facing similar distribution challenges.

The research focuses on comparing only two strategies (direct shipping and cross-docking) and the warehouse shipping strategy is not thoroughly analyzed. This limited scope might not provide a comprehensive understanding of all potential distribution strategies that could be beneficial for the tire manufacturing company. It’s suggested to conduct a more comprehensive analysis that includes a thorough evaluation of the warehouse shipping strategy.

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