JOURNAL OF TECHNOLOGY MANAGEMENT AND TECHNOPRENEURSHIP

Supply Chain Network Design Using Mixed Integer Programming for Start-up: A Case Study of Siklus Refill Indonesia

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Abstract

Supply chain network design decisions significantly affect the total supply chain costs by around 80%. This study focuses on designing a retail supply chain network to minimize total logistics costs by determining the number of facilities, location of facilities, and optimal product allocation per facility. For retailers who use last-mile delivery, the proximity between the starting and delivery destination points is essential. The supply chain network design is based on an actual case study in a retailer company: Siklus Refill Indonesia, which has a multi-echelon network, taking into account changes in the range of coverage and time of service simultaneously. The design of the company's supply chain network needs to be evaluated considering the number of demand points that must be visited, the wide service area, the uneven distribution of hub facilities in all service areas, and the exemption of costs for product delivery. An exact method with the mathematical model of Mixed Integer Programming (MIP) is used to solve this problem. The exact method can produce optimal global solutions. Nine proposed scenarios were developed to solve these problems, concurrently considering the different ranges and service times. Based on the experimental results of the proposed scenario, there is a 46.13% decrease in total logistics costs.

Keywords: Exact method, Mixed integer programming, Supply chain network design, Retail.

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1. Introduction

Facility Location Problem (FLP) is an important decision in modern logistics planning, which involves choosing the best location to deliver products or services to customers (Oyewoie & Adetunji, 2021). FLP focuses more on determining the location of the best facilities so that costs, time, distance, and risks associated with fulfilling customer demands can be minimized (Ahuja et al., 1993) (Nagy & Salhi, 2007). At this time, FLP is getting increasingly diverse and complex variants. Factors causing complexity include supply chain network conditions (echelon models, number of periods, facility capacity models, etc.), market share limitations, demand uncertainty, temporary closure of facilities, etc.

The supply chain network design is based on an actual case study in a retail company: Siklus Refill Indonesia has a multi-echelon network. Siklus Refill Indonesia uses motors to deliver products from the warehouse/hub to the final consumer by carrying the concept of last-mile delivery. In fulfilling customer orders, Siklus Refill Indonesia has one main warehouse, Cipinang Internal Warehouse located in East Jakarta, and three hubs located in Bekasi City, Tangerang City, and South Tangerang. Therefore, designing a company's supply chain network by considering the number of consumer points that must be visited, the wide service area, uneven placement of existing hub facilities in all service areas, and the existence of fee waivers need to be evaluated.

Several previous studies discussed the topic of supply chain network design with a focus on facility locations. Research for multi-echelon supply chain networks was carried out by Masudin (2013) and Rizwanullah et al. (2017). Generally, research for determining the location of facilities only considers one parameter, namely the maximum range or maximum service time in the model. For example, studies by Zhou et al. (2019), Vieira et al. (2019), and Palomino et al. (2022) only consider the maximum range limit. In this study, besides multi-echelon conditions, the limitations of the range and maximum service time for simultaneous facilities were also. considered, which had not been considered by previous studies. The service time calculation is the facility's travel time to the final consumer who has considered traffic congestion.

This study aims to minimize total logistics costs by determining the number of facilities, location of facilities, and optimal product allocation per facility using the exact method with the mathematical model of Mixed Integer Programming (MIP). The exact method is chosen because it can produce an optimal global solution. With the objective function of minimizing total logistics costs, the model considers the trade-off between facility costs from the construction of new hub facilities and transportation costs in each echelon to obtain the most optimal decision.

Research on supply chain network design focused on facility locations in multi-echelon conditions was carried out by Masudin (2013) and Rizwanullah et al. (2017). Masudin (2013) used MILP to address FLP in a case study of the LPG supply chain in Indonesia. Rizwanullah et al. (2017) added multi-product conditions to complete a three-tier supply chain network using the MIP mathematical model with the help of LINGO. Maximum range limits were considered in studies by Zhou et al. (2019), Vieira et al. (2019), and Palomino et al. (2022). Zhou et al. (2019) presented a mathematical model of the covering problem with the objective function of minimizing distribution distance and development costs in a retail distribution network to determine the location of warehouses and DCs. Vieira et al. (2019) present a two-level hierarchical facility location model for allocating cancer treatment units in Rio de Janeiro. The location and allocation of facilities are solved using the Integer Programming (IP) model to minimize the distance weight formed. Palomino et al. (2022) brought a case study on a retail company located in Colombia in choosing the most appropriate DC location considering an average maximum distance of 150 miles. In addition to the maximum range limit, the flow consolidation limitation is considered by Boujelben et al. (2012) to solve the supply chain network design problem in the automotive industry with the MIP mathematical model.

This research consists of five sections. The first section is the introduction which explains the background of the issues raised. The second section is a literature review that explains the study of literature related to theories based on problems that are relevant to the research topic. The third section discusses the research methodology for problem-solving. The fourth section discusses the data collected and the processing results obtained. Finally, the fifth section explains the conclusions based on the results that have been done previously.

2. Method

A multi-echelons supply chain is studied as a real case problem. The supply chain considers single hubs, multi-warehouses, and a set of customers. The multi-modes of transport are used to transport goods. The transportation between the main hub to warehouses using a van, while from warehouses to end customers using motorcycles. In this case, we want to evaluate the supply chain network to minimize the total cost.

This research is conducted in several steps. First, the mathematical model is developed based on a real case study and a combination of some literature. Second, the relevant data is collected. In this case, we use primary and secondary data. The hub, warehouses, customers, and vehicle attributes are the primary data, while the candidate locations of new hubs are collected based on the spatial data using google maps, the cost data used are referred from literature. Third, LINGO is used to solve the mathematical model, after the verification and validation are satisfied. Then, the numerical experiment is conducted to analyze the impact of changes in some parameters. Lastly, the conclusion is drawn after discussions are presented to describe the contribution and managerial implication of the proposed solution.

This research uses the exact method with MIP mathematical programming to solve the problem. The research objective is to minimize the total cost by determining the optimum number of operating warehouses and hubs and distributing quantities from each supply to each demand point. The exact method in FLP has been applied in various works of literature, including Correiaa & Melo (2015), Sarwar et al. (2020), and Sima (2021). Furthermore, the exact method produces a globally optimal solution to the objective function with a relatively simple approach to making decisions on complex problems (Chandra & Grabis, 2016).

The development of the MIP mathematical model is based on a previous study conducted by Sarwar et al. (2020). In the primary reference model, modifications were made by adding facility costs to the objective function and constraint that limits the covering area. The covering-based limit used refers to Gokbayrak & Kocaman (2017). The covering limitation is combining distance and service time parameters. So, the supply points only serve demand points that do not exceed the maximum range and service time limits. Here is the complete mathematical model used in this research:

- Index Sets

  J = set of warehouse locations
  K = set of customer locations
  S = set of hub locations
  L = set of products

- Parameters

  n = number of operating warehouses
  r_{kl} = number of product requirements at the customer's location k
  d_{js} = distance between warehouse location j and hub s
  d_{sk} = distance between hub location s and customer location k
  d_{jk} = distance between warehouse location j and customer location k
  c_{jk} = shipping cost from warehouse location j to customer location k
  c_{js} = shipping cost from warehouse j to hub s
  c_{sk} = shipping cost from hub s to customer location k
  c_s = fixed cost of opening a hub
  $\alpha_{k,s} = \begin{cases} 1, if\ d_{k,s} \leq Dmaks\ and\ t_{k,s} \leq Tmaks \\ \quad 0, else. \end{cases}$

- Decision Variables

  f_{jkl} = number of products from warehouse j to customer location k
  f_{jsl} = number of products from warehouse j to hub s
  f_{skl} = number of products from hub s to customer location k
  x_s = $\{1,$ if there is a hub operating at s, otherwise 0
  z_{js} = $\{1,$ if there is a warehouse operating to serve hub s, otherwise 0
  y_{sk} = $\{1,$ if there is a hub operating to serve customer locations k, otherwise 0

x_j = {1, if there is a warehouse operating at location j, otherwise 0
y_{jk} = {1, if there is a warehouse operating to serve customer locations k, otherwise 0

- Objective Function

Minimize total logistics costs.

$$\min \sum_{j\in J}\sum_{k\in K}(c_{jk} * d_{jk} * y_{jk}) + \sum_{j\in J}\sum_{s\in S}(c_{js} * d_{js} * z_{js}) + \sum_{s\in S}\sum_{k\in K}(c_{sk} * d_{sk} * y_{sk}) + \sum_{s\in S}(c_s * x_s) \tag{1}$$

- Constraints

Determine the number of warehouses opened during the entire process.

$$\sum_{j\in J} x_j = n \tag{2}$$

Ensures that only open warehouses serve the hub.

$$\sum_{s\in S} z_{js} \le x_j \qquad \forall j \tag{3}$$

Ensure that each hub is served by at least one warehouse.

$$x_s \le \sum_{j\in J} z_{js} \qquad \forall s \tag{4}$$

Ensure that only open hubs serve customer locations and that all available hubs serve at least one customer location.

$$\sum_{k\in K}(y_{jk}) \le x_j * |k| \qquad \forall j \tag{5}$$

$$\sum_{k\in K}(y_{sk}) \ge x_s \qquad \forall s \tag{6}$$

$$\sum_{k\in K}(y_{sk}) \le x_s * |k| \qquad \forall s \tag{7}$$

Ensure possible routes between warehouses and open hubs.

$$y_{jk} \le x_j \qquad \forall j, \forall k \tag{8}$$

$$z_{js} \le x_j \qquad \forall j, \forall s \tag{9}$$

Ensure only one warehouse supplies products to each hub.

$$z_{js} \le x_s \qquad \forall j, \forall s \tag{10}$$

Ensure warehouses and hubs serve specific customer locations.

$$\sum_{j\in J} z_{js} \le x_s \qquad \forall s \tag{11}$$

$$y_{sk} \le x_s \qquad \forall s, \forall k \tag{12}$$

Ensure that only one route goes to each location from the warehouse and the hub.

$$\sum_{j\in J} y_{jk} + \sum_{s\in S} y_{sk} \le 1 \qquad \forall k \tag{13}$$

Ensuring that customer demands are met.

$$\sum_{j\in J} f_{jkl} + \sum_{s\in S} f_{skl} \geq r_{kl} \qquad \forall k, \forall l \qquad (14)$$

Ensure that products are shipped only along permitted routes.

$$f_{jkl} \leq r_{kl} * y_{jk} \qquad \forall j, \forall k, \forall l \qquad (15)$$

$$f_{skl} \leq r_{kl} * y_{sk} \qquad \forall s, \forall k, \forall l \qquad (16)$$

Ensure that outbound shipments do not exceed inbound.

$$\sum_{k\in K} f_{skl} \leq \sum_{j\in J} f_{jsl} \qquad \forall j, \forall l \qquad (17)$$

Ensure all customers are served by at least one facility.

$$\sum_{k\in K} \alpha_{k,s} x_s \geq 1 \qquad \forall k \qquad (18)$$

A non-negativity constraint on product flow and the number of vehicles.

$$f \in \mathbb{R} \qquad (19)$$

A binary decision variable.

$$x, y, z \in \{0,1\} \qquad (20)$$

3. Results and Discussion

3.1. Determination of Distance Matrix, Time Matrix, and Facility Range Binary Matrix

In the proposed scenario, the required distance matrix is the distance between the internal warehouse location to the consumer point, the distance between the internal warehouse to the hub facility candidate, and from the hub facility candidate to the consumer point. Calculation of the distance in meters is obtained by processing the actual address from the location of origin to the destination location using google maps. Making a time matrix using conversion from distance to time with a fixed vehicle speed of 30 km/hour which is the maximum vehicle speed limit for residential areas according to Minister of Transportation Regulation No. 111 article 3 paragraph 4 of 2015. Apart from the distance matrix, another input in data processing is a binary matrix of the range of hub facilities to find out whether the location can reach consumers within the specified distance and time range. The value in the binary matrix will have a value of 1 if the range and service time of the hub facility to consumers is less than the maximum limit set in the scenario and will have a value of 0 otherwise.

3.2. Calculation of Transportation Costs

Transportation costs are costs incurred as a result of product delivery activities. In this case, the transportation costs involved are the variable costs incurred due to the use of fuel from the vehicles used. This fee is calculated based on the ratio of fuel consumption for transportation modes to fuel prices obtained from Pertamina's official page as of July 2022 (MyPertamina, 2022). Siklus Refill Indonesia uses 2 different modes in its product delivery process, namely blind vans, and motorbikes.

3.2.1. Transportation costs from the Internal Warehouse to the Hub

Delivery from the internal warehouse to the hub is done by blind van. Transportation costs from the internal warehouse to the hub are calculated based on:

- The fuel consumption ratio for the mode of transportation used is 1:13.5, meaning that one liter of fuel can be used to cover 13.5 km (Pemeritahkota.com 2022).
- The transportation mode of fuel for product delivery from internal warehouses to the hub uses Pertalite, so transportation costs are obtained from the division of the price of Pertalite per liter divided by the vehicle mileage per liter. Based on calculations, the transportation cost from the internal warehouse to the hub is IDR566.67/km.

3.2.2. Transportation costs from the Internal Warehouse/Hub to the Final Consumer

Delivery from the internal warehouse to the hub is carried out by automatic motorbikes. Transportation costs to final consumers are calculated based on:

- The fuel consumption ratio for the mode of transportation used is 1:52.9, meaning that one liter of fuel can be used to cover 52.9 km (Hondacengkareng.com 2022).
- The transportation mode of fuel for product delivery from internal warehouses/hubs to end consumers uses Pertalite, so transportation costs are obtained from the distribution of the price of Pertalite per liter divided by the vehicle mileage per liter. Based on the calculation of transportation costs from the internal warehouse/hub to the final consumer, which is IDR144.61/km.

3.2.3. Calculation of Hub Facility Fees

The fixed cost of hub facilities is the operating costs that arise for each opening of a hub facility, with a fixed fee of $400 per year for the opening of each facility (Pina-Pardo et al., 2022), then converting United States Dollars to Indonesian Rupiah.

$1 = IDR14,269
$400 = 400 × IDR14,269
= IDR5,707,600

The conversion of $1 to IDR14,269 is based on the conversion of the middle dollar rate (BPS 2021). Based on calculations, it is known that the fixed cost for opening each hub is IDR5,707,600 per year or IDR15,637.26 per day.

3.2.4. Calculation of Existing Conditions and Proposed Scenarios

The proposed scenario aims to determine the effect of having a hub facility in the process of shipping Siklus Refill Indonesia’s products on transportation costs. In the existing conditions, DKI Jakarta province does not yet have a hub, so all customer requests must be served directly by internal warehouses. Whereas in the proposed scenario, there is a hub that helps product distribution, where the hub candidate is the consumer point itself, according to a reference from Adhitya et al. (2022). The existence of a hub facility led to the emergence of two possibilities for product delivery to consumers. The first is direct delivery from the warehouse to the end consumer, the second is utilizing hub facilities to assist product delivery to the final consumer as illustrated in Figure 1 below.

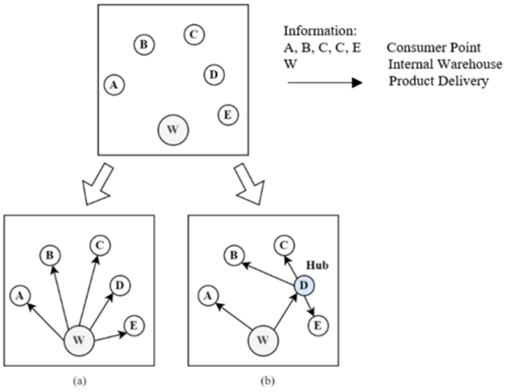


Fig. 1. Existing and propose scenarios

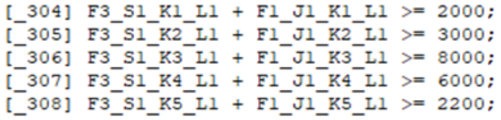
Limitations on the range and service time of hub facilities are added to the proposed scenario data processing because the number of hub facilities that can operate is unknown. As a company that promotes last-mile delivery, the closeness of the facility to the end consumer is an important thing to consider for facility utilization (Hurst, 1972). Therefore, the proposed scenario is developed by considering the distance and service time limitations that can be reached by candidate hub facilities. With the addition of these distance and time limitations, the mathematical model must be modified with covering-based constraints that consider the range and time of the facility. In last-mile delivery, the optimal distance from facilities to consumers is in the range of 5-15 km (Allen et al., 2018; Amchang, 2020; Farhan and Murray, 2006; Lopez, 2017; Mallick and Routray, 2001). Meanwhile, for the service time range, time windows of 10-30 minutes per order are used (Lindawati and Gunawan, 2016), so that under proposed conditions, 9 proposed scenarios are carried out with different combinations of range distance and service time, as detailed in Table 1 below.

Table 1. Proposed scenario

Scenario	Range Limit	
	Distance (km)	Time (minutes)
Scenario 1	5 km	10 minutes
Scenario 2	5 km	20 minutes
Scenario 3	5 km	30 minutes
Scenario 4	10 km	10 minutes
Scenario 5	10 km	20 minutes
Scenario 6	10 km	30 minutes
Scenario 7	15 km	10 minutes
Scenario 8	15 km	20 minutes
Scenario 9	15 km	30 minutes

4. Model Verification and Validation

Model verification is carried out to ensure that the model built into the system is correct and runs according to real system conditions. The following Figure 2 shows the LINGO model at constraint 14, this limitation means that products sent from both warehouse (*j*) and hub (*s*) must meet consumer demand at that location. This condition states that there is repetition in terms of checking the fulfillment of product needs for certain consumers.



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[_304] F3_S1_K1_L1 + F1_J1_K1_L1 >= 2000;
[_305] F3_S1_K2_L1 + F1_J1_K2_L1 >= 3000;
[_306] F3_S1_K3_L1 + F1_J1_K3_L1 >= 8000;
[_307] F3_S1_K4_L1 + F1_J1_K4_L1 >= 6000;
[_308] F3_S1_K5_L1 + F1_J1_K5_L1 >= 2200;
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Fig. 2. Display model in limitation 14

After verification, the next step is model validation. Model validation is intended to ensure that the model and results are in accordance with actual conditions. At this stage, it is used to check the results of LINGO processing with the expected output results. Table 2 shows the results of the validation test for the variables Fj, s, l in scenario 1, namely the number of products sent from the internal warehouse (*j*) to the hub (*s*) and limit 14 where all consumer requests can be fulfilled. The results can be said to be valid because the volume sent to the hub is equal to the total customer demand, so the limits are met.

Table 2. Variable validation test Fj, s,l and in limitation 14

Variable ($F_{j,s,l}$)	Volume (ml)	Volume Limitation (ml)	Status
F2 (J1, S1, L1)	24,750	536,220	Valid
F2 (J1, S14, L1)	13,500		
F2 (J1, S15, L1)	40,400		
F2 (J1, S37, L1)	74,450		
F2 (J1, S38, L1)	48,600		
F2 (J1, S49, L1)	37,500		
F2 (J1, S50, L1)	29,200		
F2 (J1, S51, L1)	63,700		
F2 (J1, S52, L1)	7,500		
F2 (J1, S58, L1)	40,000		
F2 (J1, S62, L1)	29,970		
F2 (J1, S66, L1)	8,700		
F2 (J1, S68, L1)	3,500		
F2 (J1, S73, L1)	13,000		
F2 (J1, S74, L1)	8,600		
F2 (J1, S75, L1)	2,000		
F2 (J1, S76, L1)	22,500		
F2 (J1, S79, L1)	37,500		

F2 (J1, S80, L1)	5,000
F2 (J1, S83, L1)	1,500
F2 (J1, S90, L1)	3,250
F2 (J1, S92, L1)	5,100
F2 (J1, S95, L1)	13000
F2 (J1, S97, L1)	3.000

The following Table 3 is a validation test for the Fs,k,l variables which describe the number of products sent from the hub (s) to consumers (k) and limit 17 which ensures that outbound shipments do not exceed inbound shipments. In this table, this limitation is fulfilled so that the results shown by the variables Fs,k,l are said to be valid.

Table 3. Variable validation test Fs, k,l in limitation 17

Variable ($F_{s,\,k,l}$)	Volume (ml)	Volume Total (ml)	Volume Limitation (ml)	Status
F3 (S1, K1, L1)	2,000	24,750	24,750	Valid
F3 (S1, K8, L1)	5,500			
F3 (S1, K20, L1)	2,000			
F3 (S1, K21, L1)	4,250			
F3 (S1, K44, L1)	11,000			

The following Table 4 presents the validation status of each variable. Processing results that do not violate the boundaries, make the model built can be said to be valid.

Table 4. Recapitulation validation of each variable

Variable	Description	Status
X_j	Warehouse availability on site *j*	Valid
X_s	Availability of hubs at location s	Valid
$Z_{j,s}$	Warehouse availability to service the hub	Valid
$Y_{s,k}$	Availability of hubs to serve consumers	Valid
$Y_{j,k}$	Availability of warehouses to serve consumers	Valid
$F_{j,k,l}$	The number of products sent from the warehouse to consumers	Valid
$F_{j,s,l}$	The number of products sent from the warehouse to the hub	Valid
$F_{s,k,l}$	The number of products sent from the hub to consumers	Valid

5. Results of Proposed Scenario

The difference between the existing and the proposed networks is that there is a hub to assist product delivery to the final consumer therefore it is expected that the distance traveled by motorists will be shorter and have a direct effect on reducing transportation costs. Under the proposed scheme, the maximum distance from the hub to the consumer is set at 5-15 km following the set threshold in previous studies (Allen et al., 2018; Amchang, 2020; Farhan & Murray, 2006; Lopez, 2017; Mallick & Routray, 2001), and service time range of 10-30 minutes (Gunawan, 2016). The objective function of the proposed model is to minimize the total logistics costs consisting of transportation costs and fixed costs for opening hub facilities. Based on these 9 scenario combinations, it is found that scenarios 1, 2, 3, 4, and 7 result in the same total logistics cost of IDR669,093 from the selection of 24 hub facilities. In scenarios 5, 6, and 8, 11 hub facilities were selected to help serve end customers with a total logistics cost of IDR356,936. Meanwhile, from scenario 9 with a distance limit of 15 km and a service time of 30 minutes, the number of selected hub facilities is 5 and the total logistics cost is IDR232,921.

6. Discussion

In the existing conditions in the Jakarta area, Siklus Refill Indonesia does not have a hub facility hence product delivery is carried out directly from the internal warehouse to the customer's point so motorbikes have to travel long distances and take a long time to fulfill demand. Therefore, 9 combinations of proposed scenarios were made which were reviewed from the range of distance and service time of the facility with the objective function of minimizing total logistics costs. A comparison of transportation costs in existing and proposed scenarios can be seen in Table 5.

Table 5. Comparison of transportation cost (in IDR)

Proposed Scenario	Transportation Cost of Proposed Scenario	Transportation Cost of Existing Scenario	Transportation Cost Deviation
Scenario 1	293,799	287,224	Increased by 2,29%
Scenario 2			Increased by 2,29%
Scenario 3			Increased by 2,29%
Scenario 4			Increased by 2,29%
Scenario 5	184,927		Decreased by 35,62%
Scenario 6			Decreased by 35,62%
Scenario 7	293,799		Increased by 2,29%
Scenario 8	184,927		Decreased by 35,62%
Scenario 9	154,734		Decreased by 46,13%

Facility costs are influenced by the number of facilities selected, in which the more facilities selected, the more facility costs incurred. The existence of limitations on the range and service time of the hub facilities affects the number of selected hubs. In general, the closer the range of facilities is, the more facilities will be selected, and vice versa, the farther the range of facilities, the fewer facilities will be selected (Adhitya et al., 2022; Amchang, 2020). Similar to the range of service time for facilities, (Badri et al., 1998) varied the service time for facilities. Based on his research, it is known that the smaller the range of service time for facilities, the greater the number of facilities needed to serve customers.

The general idea conveyed from several studies is the same as the experimental results. A graph of the number of selected hub facilities from the 9 proposed scenarios with different ranges and service times can be seen in Figure 3.

Fig. 3. Number of the selected hub facility

In this study, transportation costs are calculated based on the use of vehicle fuel which is influenced by fuel costs and vehicle mileage. Studies by (Adhitya et al., 2022; Vieira et al., 2019; Ye et al., 2015) generate the idea that the smaller the range or time of reaching a facility, the more facilities will be selected, the larger the number of selected facilities, the lower the average mileage traveled by business people/customers. From this idea, it can be concluded that the relationship between the distance or time of reaching the facility with the distance traveled by the vehicle is directly proportional. However, this is not in accordance with the results of the research from the 9 proposed scenarios.

Table 5 demonstrates transportation costs incurred in each proposed scenario. Referring to the previous idea, scenarios 1, 2, 3, 4, and 7 which have the greatest number of facilities should result in lower transportation costs than the other scenarios because the average distance between hubs and customers is closer. However, the results of the study show the opposite, where those scenarios 1, 2, 3, 4, and 7 have the highest transportation costs, while scenario 9 with the fewest number of hub facilities produces the smallest transportation costs compared to the proposed scenario. This result occurs because the model takes multi-echelon conditions into account. Delivery does not only consider one echelon, namely from the hub to the final customer but also considers delivery from the internal warehouse to the hub as well as from the internal warehouse to the customer. In addition, deliveries from internal warehouses to hubs using blind vans cost almost 4 times more than shipping from hubs to end customers or internal warehouses to customers using motorbikes. Therefore, scenarios 1, 2, 3, 4, and 7 do not produce more cost-effective scenarios compared to the remaining others. Even though scenarios 1, 2, 3, 4, and 7 have the distance from the hub to the closest consumer, due to the greater number of selected facilities, the frequency of delivery to the hub using a blind van, increases so that transportation costs also increase.

The research objective function here is to minimize the total logistics costs incurred which include facility and transportation costs. The presence of more than one cost component makes it difficult to predict the trend of decreasing or increasing costs. For example, research by (Palomino et al., 2022), also aims to minimize total logistics costs by covering two cost components: transportation and fixed costs for opening a warehouse. Following their research, the idea taken is that there is no specific trend of the effect of the number of facilities on the total logistics costs generated. The greater the number of facilities does not mean the smaller or the bigger the total logistics costs incurred. Their optimal result obtained is described in a scenario that has the lowest trade-off between shipping and fixed cost.

Figure 4 shows the total logistics costs of the 9 proposed scenarios. In the case study of Siklus Refill Indonesia, it was previously known that the greater the distance and time range, the fewer facility costs and transportation costs are generated, so the idea can be taken that in this study the farther the distance range and the longer the time range is directly proportional to the total logistics costs produced. The lowest total logistics cost is found in scenario 9 with IDR232,921. Total logistics costs in scenario 9 are 46.65% lower compared to scenarios 5, 6, and 8, and 65.19% lower than scenarios 1, 2, 3, 4, and 7.

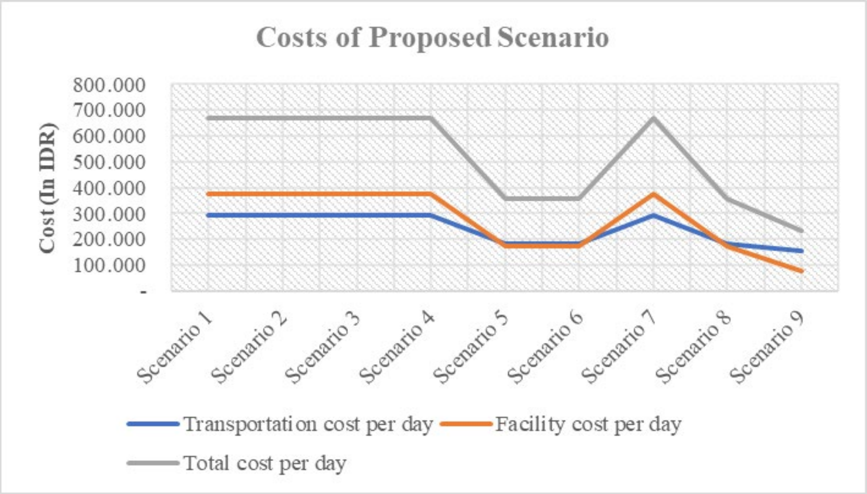

Fig. 4. Cost components comparison

7. Conclusion

The Siklus Refill Indonesia supply chain network's design results employ the proposed scenario with 9 simultaneous combinations of different ranges of range and range of service times. The first scenario uses a distance limit of 5 km and a service time of 10 minutes, the second scenario uses a distance limit of 5 km and a service time of 20 minutes, the third scenario uses a distance limit of 5 km and a service time of 30 minutes, the fourth scenario uses a distance limit of 10 km and a service time of 10 minutes, the fifth scenario uses a distance limit of 10 km and a service time of 20 minutes, the sixth scenario uses a distance limit of 10 km and In scenarios 1, 2, 3, 4, and 7, 24 hub facilities were chosen to assist in meeting consumer demand, at a total logistics cost of IDR669,093. The number of selected hub facilities in scenarios 5, 6, and 8 is 11, with a total cost of IDR356,936. In scenario 9, 5 hub facilities with a total logistics cost of IDR232,921 were chosen. It can be seen that by varying the range of distance and service time limits, the total logistics cost of the proposed scenario can be reduced by up to 65.19%. In order to determine the best scenario for the company, Siklus Refill Indonesia must first determine the desired service level based on the range and service time span of hub facilities. Siklus can use scenario 9, because it results in the greatest reduction in transportation costs, up to 46.13% when compared to the current conditions. The implementation of this proposed scenario maintains the hub facility's reach to consumers, which is in the optimal range for last-mile delivery.

8. Recommendations

It is possible to develop models that incorporate routing and traffic congestion so that the results obtained are more accurate. In addition, several supply chain-related policies, such as inventory policies, sourcing policies, and production policies, can be considered when developing models. This certainly encourages additional research to involve members of a broader supply chain network, such as by involving multi-tiered suppliers. The recommended method for future research is to use a simulation approach to test the performance of the supply chain network design by implementing multiple related policies.

Acknowledgments

This article was presented as an oral presentation at the APSKI International Conference on Entrepreneurship (www.apski.net) held in Bandung, Indonesia on May 29-30th, 2023.

References

Adhitya, A., Meyland, Nauli, M. A., Tjahjono, M., & Halim, I. (2022). Applying Greenfield Analysis for Optimal Planning of COVID-19 Vaccination Outreach: A Case Study of Bali Province. Operations and Supply Chain Management, 15(2), 205–217. https://doi.org/10.31387/oscm0490341

Ahuja, R. K., Magnanti, T. L., & Orlin, J. B. (1993). Network Flows: Theory, Algorithms and Applications. Prentice Hall.

Allen, J., Piecyk, M., Piotrowska, M., McLeod, F., Cherrett, T., Ghali, K., Nguyen, T., Bektas, T., Bates, O., Friday, A., Wise, S., & Austwick, M. (2018). Understanding the Impact of E-commerce on Last-mile Light Goods Vehicle Activity in Urban Areas: The Case of London. Transportation Research Part D: Transport and Environment, 61, 325–338. https://doi.org/10.1016/j.trd.2017.07.020

Amchang, C. (2020). The Coverage Area for Extended Delivery Service in Eastern Economic Corridor (EEC): A Case of Thailand Post Co., Ltd*. Chompoonut AMCHANG / Journal of Distribution Science, 18(4), 39–50. https://doi.org/10.15722/jds.18.4.202004.39

Badri, M. A., Mortagy, A. K., & Alsayed, A. (1998). A Multi-objective Model for Locating Fire Stations. In European Journal of Operational Research (Vol. 110).

Boujelben, M. K., Gicquel, C., & Minoux, M. (2012). A supply chain network design problem under flow consolidation constraints. Proceedings of MOSIM'12. http://hal.archives-ouvertes.fr/docs/00/72/86/36/PDF/paper_20.pdf

BPS. 2021. "No Title." Diambil (https://www.bps.go.id/indicator/13/284/1/kurs-tengah-beberapa-mata-uang-asing-terhadap-rupiah-di-bank-indonesia-dan-harga-emas-di-jakarta.html).

Chandra, Charu, dan Janis Grabis. 2016. Supply Chain Configuration: Concepts, Solutions, and Applications. 2 ed. Springer.

Correiaa, Isabel, dan Teresa Melo. 2015. Multi-period capacitated facility location under delayed demand satisfaction.

Farhan, B., & Murray, A. T. (2006). Distance Decay and Coverage in Facility Location Planning. Annals of Regional Science, 40(2), 279–295. https://doi.org/10.1007/s00168-005-0041-7

Gunawan, A. (2016). Minimizing Waiting Time in Last Mile Delivery for Smart City.

Gokbayrak, Kagan, dan Ayse Selin Kocaman. 2017. "A distance-limited continuous location-allocation problem for spatial planning of decentralized systems." Computers and Operations Research 88:15–29. doi: 10.1016/j.cor.2017.06.013.

Hondacengkareng.com. 2022. "Daftar Konsumsi BBM Sepeda Motor Honda." Diambil (https://www.hondacengkareng.com/daftar-konsumsi-bbm-sepeda-motor-honda/).

Hurst, MEE. 1972. A Geography of Economic Behavior: An Introduction. North Scituate, MA: Duxbury.

Lindawati, dan Aldy Gunawan. 2016. "Minimizing waiting time in last mile delivery for smart city." 1–10.

Lopez, E. (2017, July 21). Last Mile Distances Shrink as Logistics Infrastructure Grows. https://www.supplychaindive.com/news/last-mile-distance-decrease-delivery-time-infrastructure/447067/

Mallick, R. K., & Routray, J. K. (2001). Identification and Accessibility Analysis of Rural Service Centers in Kendrapara District, Orissa, India: A GIS-based Application (Vol. 3).

Masudin, I. (2013). Facility Location Modeling in Multi-Echelon Distribution System: A Case Study of Indonesian Liquefied Petroleum Gas Supply Chain. Aceh International Journal of Science and Technology, 2(1), 37–43. http://www.jurnal.unsyiah.ac.id/AIJST/article/view/595

MyPertamina. 2022. "HARGA BBM PERTAMINA." Diambil (https://mypertamina.id/fuels-harga).

Nagy, G., & Salhi, S. (2007). Location-routing: Issues, models and methods. Eur. J. Oper. Res, 177, 649–672.

Oyewoie, G. J., & Adetunji, O. (2021). Solving the Facility Location and Fixed Charge Solid Transportation Problem. Journal of Industrial and Management Optimization, 17(4), 1557–1575. https://doi.org/10.3934/jimo.2020034

Palomino, K., Garcia, D., & Berdugo, C. (2022). A MILP Facility Location Model with Distance Value Adjustments for Demand Fulfillment Using Google Maps. Journal of Engineering Research (Kuwait), 10(2 A), 270–291. https://doi.org/10.36909/jer.10473

Pemerintahkota.com. 2022. "Konsumsi Bensin Gran Max dan Kapasitas Tangki Nya." Diambil (https://pemerintahkota.com/bensin-gran-max/).

Pina-Pardo, Juan C., Matheo Moreno, Miguel Barros, Alexandre Faria, Matthias Winkenbach, dan Milena Janjevic. 2022. "Design of a two-echelon last-mile delivery model." EURO Journal on Transportation and Logistics 11(April):100079. doi: 10.1016/j.ejtl.2022.100079.

Rizwanullah, M., Kaanodiya, K. K., & Verma, S. K. (2017). Cite this paper as : MODELING OF SUPPLY CHAIN DYNAMICS : A LINGO BASED THREE-TIER. 4(01), 24–32.

Sarwar, Ferdous, Azim Sarwar, Israt Humayra, dan Navid Anas Sadman. 2020. "Supply chain network optimization strategy in last-mile delivery using crowdsourced approach: A case study." Proceedings of the International Conference on Industrial Engineering and Operations Management (August):189–200.

Sima, Said A. 2021. "Mathematical Programming Model for the Two-Level Facility Location Problem: The Case of Tanzanian Emergence Maize Distribution Network for 2004–2010 Maize Data." Tanzania Journal of Science 47(3):1020–32. doi: 10.4314/tjs.v47i3.13.

Vieira, I. F. G., de Barros, M. F., & Cormack, A. (2019). Hierarchical Facility Location Model for Allocating Cancer Treatment Units in Interior of Rio de Janeiro. Production, 29, 1–13. https://doi.org/10.1590/0103-6513.20190026

Ye, F., Zhao, Q., Xi, M., & Dessouky, M. (2015). Chinese National Emergency Warehouse Location Research based on VNS Algorithm. Electronic Notes in Discrete Mathematics, 47, 61–68. https://doi.org/10.1016/j.endm.2014.11.009

Zhou, X., Xu, M., Li, S., & Lu, Q. (2019). Research on Location Problem of Distribution Center based on Coverage Location Model. 80(Bems), 459–462. https://doi.org/10.2991/bems-19.2019.81