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Supply Chain Design of Used-Cooking Oil for Biofuel: A Case Study in Special Region of Yogyakarta

Rianti Indah Lestari *

Politeknik ATI Makassar, Jl. Sunu No.220, Makassar, Sulawesi Selatan, 60236

ABSTRACT

Biofuels have been seen as alternative fuels in response to the scarcity of fossil fuel sources. Biodiesel can be produced from industrial and municipal waste, such as used cooking oil as a substitute for fossil fuels. Indonesia's high cooking oil consumption provides an excellent opportunity for biofuel production. Due to the increased potential and availability of used cooking oil in the culinary industry, biofuel production from used cooking oils seems promising, particularly in areas where the culinary industry is dominant, such as in the Special Region of Yogyakarta, Indonesia. Supported by a pilot plant of biofuel production from used cooking oil, it implies the potential to upscale the production toward an industrial scale. Hence, supporting the production efficient and effective supply chain to support production is necessary. Since the sources of used cooling oil are scattered, designing the supply chain is challenging. The present paper proposes an optimized supply chain design to support biofuel production from the used cooking oils, including location, quantity, capacity, and material allocation. The Special Region of Yogyakarta was taken as a studied case. The Mixed Integer Linear Programming (MILP) model was developed and solved by a CPLEX optimizer. Results show that the potential depots are located in Danurejan, Depok, Jetis, Pengasih, and Playen, with four collection tanks, two small tanks with a capacity of 660 L/day in Danurejan and one medium tank in Depok-Sleman Progo with a capacity of 940 L/day. The total cost of the optimized supply chain is estimated to be IDR 3,047,280 /day for waste collection, transportation, vehicle, and biofuel plant costs.

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***Correspondence**

Rianti Indah Lestari
indahrianty@atim.ac.id

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1. Introduction

Energy is generally used for transportation, industry, household, and other activities. From the aspect of consumption, Indonesia's energy use has increased yearly. Based on data from the Ministry of Energy and Mineral Resources, the transportation sector is still the largest user of petroleum, especially fuel oil (BBM), reaching 65% compared to other industries. Meanwhile, the 2018 Annual Report from the Directorate General of Oil and Gas, a department under the oil reserves have experienced a downward trend over the past ten years, from 8.21 billion barrels in 2008 to around 7.5 billion barrels in 2018. Increased fuel use not supported by the ability to supply will result in the depletion of fuel reserves. Therefore, to overcome these problems, it is necessary to utilize renewable energy that has the potential to be developed as alternative energy, one of which is biofuel. Two types of biofuels for transportation are used to replace gasoline and diesel, namely ethanol and biodiesel. Ethanol is generally produced through the fermentation process of plant carbohydrates or sugars such as corn, wheat, sugar cane, and sugar beets, and it can be mixed with gasoline.

Meanwhile, biodiesel is produced through the esterification of fats from vegetable oils such as rapeseed, palm, soybean, waste cooking and fat (Bailey, 2013). In addition, biofuels are also produced from biomass. Biomass is divided into several categories: virgin wood, energy crops, agricultural products, food waste, and industrial and co-products. Food crops are still the raw material for biofuel production, so there is concern that they will compete with their use as food. Due to the impact, several studies have been conducted on raw materials to replace these foodstuffs. Some of the studies include biodiesel production using waste sunflower cooking oil, waste canola cooking oil (waste canola oil), and used cooking oil (Hossain *et al*., 2009; Sharif Hossain *et al*., 2010; Rahadianti *et al*., 2010; Agustian and Praptijanto, 2010; Kapuji *et al*., 2021; Ahmad *et al*., 2016; Wahyudi *et al*., 2020).

According to Rajasa (2023), the Minister of Trade, Muhammad Lutfi, outlined the need for cooking oil for households is estimated at 3.9 million litres in 2022. Based on this cooking oil demand data, Indonesia can develop biodiesel from used cooking oil. Used cooking oil needs to be reused. In addition to improving its quality and productivity, reprocessing used cooking oil can reduce risks to health and environmental pollution. If seen from its potential and the rapid development in terms of trade, especially the culinary industry, Yogyakarta can be one of the cities for developing biofuels from used cooking oil.

With the potential for used cooking oil from the trade sector and supported by the construction of a mini biofuel plant in Yogyakarta, this research will propose the design of a raw material supply chain network that aims to determine whether used cooking oil produced from supplier sources can meet the supply of used cooking oil for biofuel production to meet the needs of fuel, especially diesel-fueled vehicles in Yogyakarta. The first step to finding out the potential and amount of raw materials is to map the existing used cooking oil suppliers in Yogyakarta. After mapping the suppliers, the design of the used cooking oil supply chain network at a strategic level is carried out, which includes the location, quantity, capacity, and distribution of raw materials that minimize costs.

The paper is structured into seven sections. The motivation of the present study is addressed in this section, followed by a review of existing literature designing biofuel networks in Section Two. Section Three presents the approach implemented in the present study. The developed mathematical model is presented in Section Four, followed by results in Section Five and a discussion in Section Six. Section Seven concludes and presents directions for future research.

2. Literature Review

Several studies have been conducted on the design of supply networks for biofuels using biomass. Rifqie and Subandi (2010) have researched the potential suppliers of used cooking oil for biodiesel production in Malang city by mapping used cooking oil-producing companies and the production capacity of each company. The method used was a general and in-depth interview method. Based on the data analysis, it was concluded that companies that have the potential to produce used cooking oil are those from franchise restaurants (main product is fried chicken), traditional restaurants (main product is fried chicken), traditional restaurants (main product is non-fried chicken), chips and crackers industry, and hotel kitchens.

Mapping of potential used cooking oil suppliers was also conducted by Sheinbaum-Pardo *et al*. (2013). Used cooking oil data was estimated from cooking oil consumption in 2008-2010. This potential used cooking oil is used to produce biodiesel in Mexico. Developing biodiesel from used cooking oil that has been collected is expected to reduce CO2 emissions and costs. In addition, Liang *et al*. (2013) analyzed the potential suppliers of used cooking oil in China. Used cooking oil was estimated from the use of cooking oil. This study compares the emissions produced between biofuels from used cooking oil and fossil fuels.

Yong *et al*. (2012) also analyzed the demand, possibilities, constraints, and suggestions for using cooking oil-producing restaurants to develop the biodiesel supply chain in China. Based on these objectives, a questionnaire was designed to survey 246 restaurants in Nanjing. The questionnaire included basic information about the restaurants, disposal of used cooking oil, level of concern and treatment of used cooking oil recycling, suggestions for biodiesel development, and willingness to participate in biodiesel production. Factor analysis was used to analyze the used cooking oil-producing restaurants, and cluster analysis was used to group the 246 restaurants into three groups. Hopefully, this research will engage restaurants as biodiesel suppliers and promote used cooking oil biodiesel from a health perspective.

In addition to mapping and analyzing potential suppliers, studies that design the supply chain include those conducted by Ramos *et al*. (2013), who designed the supply chain at the tactical level by planning routes in the collection of used cooking oil. The goal is to minimize total fixed and variable costs. This collection uses the Multi Depot Vehicle Routing Problem with Mixed Closed and Open inter Depot Routes (MDVRP-MCO) method. This research is modeled using Mixed Integer Linear Programming (MILP) with capacity and duration as constraints. Another study was conducted by Kelloway *et al*. (2013), who built a design based on the Mcgyan process to produce biodiesel with used cooking oil and soybean seed oil as raw materials. The method used is MILP to find the optimal location and capacity of a small-scale facility for biodiesel with the Mcgyan process in London. The goal is to maximize profit.

Another study was conducted by Gunnarsson *et al*. (2004), who researched the fuel supply from forest products. This research was conducted by building a decision support tool for the supply chain at the strategic and tactical levels. The method used is a heuristic approach with Linear Programming (LP). The goal is to minimize total costs. In addition, research by Kanzian *et al*. (2013) also focuses on designing supply chains at the strategic and tactical levels to choose the optimal transportation mode, route, and location. The raw material used is forest products. Multi-Objective Optimization (MOO) is used in formulating the problem, namely where profits are maximized, and CO_2 emissions must be minimized. For this reason, Pareto analysis is used to achieve a trade-off between these objective functions by using weighted sum scalarization by changing the weight of the profit to minimize CO_2. Mansoornejad *et al*. (2013) designed a supply chain network at a strategic level with forest raw materials using methods, namely scenarios with a supply network approach and scenarios with Mixed Integer Stochastic Programming (MISP). The goal is to maximize profits.

In addition, Ng *et al*. (2013) designed a rubber seed supply network to support environmentally friendly energy demand in Malaysia. The method used is MILP. The network model is displayed for the selection of the volume of raw materials for the factory. The research objective is to maximize profits. Kim *et al*. (2011) built a supply chain network at the strategic level. They built an optimization model to make decisions for biofuel facilities, including location, quantity, supply network, and transportation logistics from raw materials to factories and factories to end consumers. The goal is to maximize profits. The MILP model is used as a solution method. Sadjady and Davoudpour (2012) designed a supply chain network at capacity at each facility. The problem includes the location and size of factories and warehouses and determining the best product distribution strategy, such as selecting transportation modes. The method used is MILP to minimize transportation costs, lead time, product storage costs, and facility construction and operation costs. Parker (2010) built a lignocellulosic supply chain optimization for biofuel feedstock using Geographic Information System (GIS). The information generated by GIS includes raw materials, potential and existing refinery locations, and transportation networks. The method used is MILP. The goal is to maximize profit.

In contrast to previous studies utilizing used cooking oil for biofuel, some have focused only on mapping the raw materials. In addition, other studies also perform optimization with predetermined data. Meanwhile, in this study, the design of the raw material supply network begins with mapping the potential of used cooking oil raw materials, after which it is continued with determining the location of the factory, capacity, and allocation of biofuel to meet fuel needs, especially in the Special Region of Yogyakarta (DIY). This study uses the Mixed Integer Linear Programming (MILP) model to obtain the optimal solution of the system to obtain the location of facilities and the allocation of facilities that minimize the total cost, which includes the cost of opening a biofuel plant, the cost of procuring a depot, the cost of purchasing vehicle, and transportation costs.

3. Methodology

The present study deployed Mixed Integer Linear Programming (MILP) to obtain the optimized supply chain design, including biofuel plant allocation location and supply chain network with the minimum total costs, including total investment costs, depot procurement costs, and transportation costs. A CPLEX optimizer solved the mathematical model. Both primary and secondary data were collected, described as the following.

3.1 Data collection

Raw material data was collected from 303 used cooking oil suppliers from 20 fast food restaurants, 153 food industries, and 129 caterers spread across Yogyakarta, which consists of four regencies and one city including Sleman Regency, Bantul Regency, Kulon Progo Regency, Gunung Kidul Regency, and Yogyakarta City. Used cooking oil data is estimated from DIY's daily cooking oil consumption. The average amount of cooking oil consumed daily is 35 litres/day for fast food restaurants, 3 litres per day for the food industry, and 5 litres per day for catering. The supplier mapping results show that the raw materials produced daily is 2,561 litres.

Determining the bin's location used a gravity location model based on the coordinates of the supply source. After obtaining the location of the new facility is assumed based on the site of the largest oil producer. The largest oil producers are located in Danurejan and Depok-Sleman sub-districts. Determination of depot capacity is obtained from Commercial Waste and Recycling Services information. This study assumed two types of depots: two bin units with a capacity of 660 litres/day and two bin units with a total of 940 litres.

The plant was determined based on investment potential and regional characteristics in DIY. The plant capacity was estimated from Mugi and Harjanto's (2011) research on ethanol plant design with a total of 1000 litres/day with a plant construction cost of IDR 1,509,693,972 So, the proposed biofuel plant has a capacity of 3000 litres/day. For the estimated development cost, a calculation using the parametric method is used.

The mode of transportation used is a three-wheeled motorcycle. This motor is used to transport used cooking oil feedstock to the depot and the biofuel plant. The bike price refers to the price of a three-wheeled motorcycle in 2022. The transportation flow starts from the supply source to the bins or the biofuel plant. The calculation of transportation costs based on fuel efficiency against vehicle capacity follows Casadei and Broda (2008).

$$\text{constant of fuel efficiency with load} = 1 - \frac{(\text{fuel efficiency per 0,45 kg} \times \text{conversion litre to kg} \times \text{the number of feedstock delivered})}{\text{conversion 100 lb to kg}} \quad (1)$$

$$\text{transportation cost} = \frac{(\text{the diesel fuel cost per litre} \times \text{distance matrix between facilities})}{(\text{the distance traveled of diesel fuel per litre for fuel efficiency unload} \times \text{constant of fuel efficiency with load}} \quad (2)$$

3.2 The development of the mathematical model

The mathematical model was developed using MILP. The components of the mathematical model are the distance between the supply source to the depot and from the supply source to the biofuel plant, the investment cost of building the plant, the cost of procuring the bins, the cost of purchasing transportation facilities, and transportation costs. The model constraints include used cooking oil supply, collection bins, and plant capacity. At the same time, the objective function is to optimize the used cooking oil supply chain network to minimize transportation and plant construction costs.

The model was built using Microsoft Excel 2010 to define the optimization problem in spreadsheet form. Components that must be defined include parameters or data, decision variables, objective functions, and constraints. After the model is built, it is solved with the CPLEX optimizer.

3.3 Sensitivity Analysis

This analysis is conducted to determine the effect of changes in parameter values on decision variables and objective function values. This research will analyse the impact of the increased use of cooking oil on the decision to open depots and factories and its effect on the objective function, namely the total cost.

4. Results

4.1 System characterization

Biofuel made from cooking oil is used for fuel mixture, mainly diesel fuel in transportation. In this study, the biofuel mixture is 5%. So that 5% of diesel fuel needs will be replaced by 5% biofuel, 17500 litres/day. The used cooking oil supply network in Special Region of Yogyakarta is a supply flow that focuses on the flow for the upstream level consisting of supply sources, depots, and biofuel plants. The used cooking oil supply flow starts from the supply source *i*. It will be sent to a temporary collection point (depot), either medium-bin *J* or small-bin *j*, or directly to the biofuel plant *K*. Based on the bin location data described in the previous sub-chapter. The bin will be located in the Danurejan sub-district (J_1 and j_1) and the Depok-Sleman sub-district (J_2 and j_2). This study assumes that two bins will be placed in each sub-district, namely, one container with a small capacity and one with a medium capacity. The basic model of the used cooking oil supply network for biofuel in Yogyakarta can be seen in Figure 1.

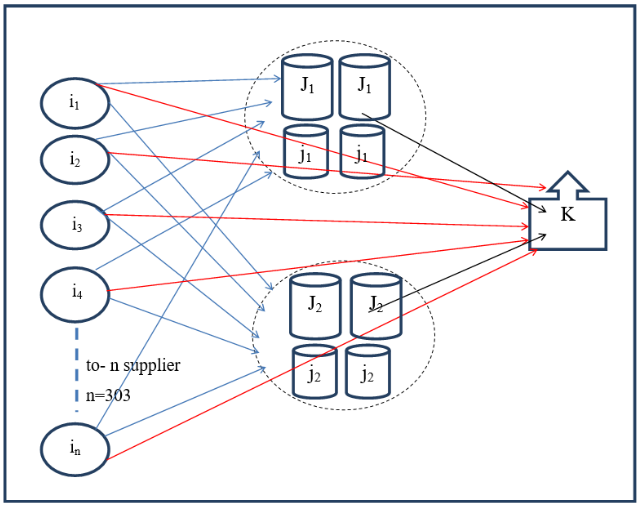

Figure 1. Used Cooking Oil Network

4.2 Mixed-integer linear programming model

4.2.1 Variables

Si	Daily amount of used cooking oil produced at point *i* (litre)
Gj	Daily capacity of a medium-scale bin at point *J* (litre)
gj	Daily capacity of a small-scale bin at point *j* (litre)
Kk	Daily capacity of the biofuel plant at point *k*
Pj	The procurement cost of a depot for the medium-scale collection of used cooking oil *J*
pj	The procurement cost of a depot for a small-scale collection of used cooking oil *j*
Fk	Investment cost of biofuel plant *k*
T	Vehicle purchase cost
TC	Transportation cost
dij	distance from supplier source *i* to depot *j* (km)
djk	distance from depot *j* to biofuel plant *k* (km)
dik	distance from supplier *i* to biofuel plant *k* (km)
C	cost of a litre of fuel = Rp6900,00
Dmt	mileage of one litre of fuel for a three-wheeled motorcycle (km/litre)
Emt	Efficiency reduction per 0.45 kg of oil for a three-wheeled motorcycle
FCDL	Fixed cost of opening medium depo
FCDS	Fixed cost of opening small depo
FCPL	Fixed cost of opening biofuel plant

1 litre of fuel = 0.9 kg

100 lb = 0.45 kg

4.2.2 Decision variables

Xij	The amount of feedstock delivered from the supplier at point *i* to the depot at point *j*
Xjk	The amount of feedstock delivered from the depot at point *j* to the biofuel plant at point *k*
Xik	The amount of feedstock delivered from the supplier at point *i* to the biofuel plant at point *k*
Yj	Binary variable 0 and 1, 1 if selecting a medium scale depot, 0 if not selected
yj	Binary variable 0 and 1, 1 if selecting a small scale depot, 0 if not selected

Yk Binary variable 0 and 1, 1 1 if selecting a biofuel plant, 0 if not selected

4.2.3 Objective function

a. Fixed Cost of Opening Facilities

1. Fixed cost of opening medium depo

$$\mathrm{FCDL} = \sum_{j=1}^{J}(P_j\, Y_j) \quad (3)$$

2. Fixed cost of opening small depo

$$\mathrm{FCDS} = \sum_{j=1}^{J}(p_j\, y_j) \quad (4)$$

3. Fixed cost of opening biofuel plant

$$\mathrm{FCPL} = \sum_{k=1}^{K}(F_k\, Y_k) \quad (5)$$

b. Transportation Cost

1. Transportation cost of flow raw materials from the supplier to the depot

$$\mathrm{TC}_1 = \frac{C\times\sum_{i=1}^{I}\sum_{j=1}^{J} d_{ij}}{\mathrm{Dmt}\times E_{mt}} \quad (6)$$

2. Transportation cost of flow raw materials from depot to biofuel plant

$$\mathrm{TC}_2 = \frac{C\times\sum_{j=1}^{J}\sum_{k=1}^{K} d_{jk}}{\mathrm{Dmt}\times E_{mt}} \quad (7)$$

3. Transportation cost of flow raw materials from supplier to biofuel plant

$$\mathrm{TC}_3 = \frac{C\times\sum_{i=1}^{I}\sum_{k=1}^{K} d_{ik}}{\mathrm{Dmt}\times E_{mt}} \quad (8)$$

For *Emt* calculation using equations (1) and (2)

$$\mathrm{TC}_1 = \frac{C\times\sum_{i=1}^{I}\sum_{j=1}^{J} d_{ij}}{\mathrm{Dmt}\times\left(1-\frac{(0.007\times0.9\times X_{ij})}{0.45}\right)} \quad (9)$$

$$\mathrm{TC}_2 = \frac{C\times\sum_{i=1}^{I}\sum_{j=1}^{J} d_{jk}}{\mathrm{Dmt}\times\left(1-\frac{(0.007\times0.9\times X_{jk})}{0.45}\right)} \quad (10)$$

$$\mathrm{TC}_3 = \frac{C\times\sum_{i=1}^{I}\sum_{j=1}^{J} d_{ik}}{\mathrm{Dmt}\times\left(1-\frac{(0.007\times0.9\times X_{ik})}{0.45}\right)} \quad (11)$$

$$\text{Minim}ize\ Z = \{\mathrm{FCPL} + \mathrm{FCDS} + \mathrm{FCPL} + \mathrm{TC}_1 + \mathrm{TC}_2 + \mathrm{TC}_3\} \quad (12)$$

4.2.4 Constraints

1. A constraint where the total amount of used cooking oil produced per day is more than or equal to the amount of used cooking oil transferred from the supply source to the depot or the biofuel plant.

$$\sum_{i=1}^{I} S_i \geq \sum_{i=1}^{I}\sum_{j=1}^{J} X_{ij} + \sum_{i=1}^{I}\sum_{k=1}^{K} X_{ik} \quad (13)$$

2. A constraint where the total amount of used cooking oil produced per day is more than or equal to the amount of used cooking oil transferred from the depot to the biofuel plant.

$$\sum_{i=1}^{I}\sum_{j=1}^{J} X_{ij} \leq \sum_{j=1}^{J}\sum_{k=1}^{K} X_{jk} \quad (14)$$

3. Constraints are binary variables to decide which small depot or medium depot to choose

$$\sum_{j=1}^{J} Y_j + \sum_{j=1}^{J} y_j \leq 1 \quad (15)$$

4. The constraint is allocating raw materials from the source supplier to the depot, where the distribution should not exceed the maximum capacity of the medium-scale depot.

$$\sum_{i=1}^{I}\sum_{j=1}^{J} X_{ij} \leq \sum_{j=1}^{J} G_j Y_j \quad (16)$$

The constraint is the allocation of raw materials from the source supplier to the depot, where the distribution should not exceed the maximum capacity of the small-scale depot.

$$\sum_{i=1}^{I}\sum_{j=1}^{J} X_{ij} \le \sum_{j=1}^{J} g_j y_j \quad (17)$$

5. The constraint is the feedstock allocation from source suppliers to the plant, where the distribution should not exceed the maximum capacity of the biofuel plant.
$$\sum_{i=1}^{I}\sum_{k=1}^{K} X_{ik} \le \sum_{k=1}^{K} K_k Y_k \quad (18)$$

6. The constraint is the allocation of feedstock from the depot to the plant, where the distribution cannot exceed the maximum capacity of the biofuel plant.
$$\sum_{j=1}^{J}\sum_{k=1}^{K} X_{jk} \le \sum_{k=1}^{K} K_k Y_k \quad (19)$$

7. The balance constraint is that the total allocation of raw materials to depots and factories equals the outgoing distribution from suppliers.
$$\sum_{i=1}^{I} S_i = \sum_{i=1}^{I}\sum_{j=1}^{J} X_{ij} + \sum_{i=1}^{I}\sum_{k=1}^{K} X_{ik} \quad (20)$$

8. The balance constraint is that the total allocation of raw materials to the plant equals the distribution out of the depot.
$$\sum_{i=1}^{I}\sum_{j=1}^{J} X_{ij} = \sum_{j=1}^{J}\sum_{k=1}^{K} X_{jk} \quad (21)$$

9. Constraints where each decision variable cannot be negative
$$X_{ij} \ge 0, X_{jk} \ge 0, X_{ik} \ge 0, Y_j \ge 0, y_j \ge 0, Y_k \ge 0, y_k \ge 0 \quad (22)$$

Several assumptions are used to calculate depot procurement costs, biofuel plant construction costs, and vehicle purchase costs. The assumptions include facilities life cycle (depots, factories, and transportation equipment), capacity, and interest rates. The calculation is based on the equal payment series capital recovery amount equation using a daily basis and an operating time of 300 days/year.

5. Optimized Supply Chain Network

Based on the mathematical model built and optimized using the CPLEX optimizer, the optimized supply chain network obtained is presented in Table 1 dan Table 2 and illustrated in Figure 3.

Table 1. Selected facilities (base model)

Item	Selected facilities		
	Collection Bin		Plant
	Danurejan (j_1)	**Depok (J_2)**	
Fixed cost (day)	1099,8	1099,8	1308441
Capacity of facilities	1880	1880	3000
Facilities selection	0	1	0
Fixed cost (day)	926,4	926,4	
Capacity of facilities	1320	1320	
Facilities selection	1	0	

Table 2. Flow of used cooking oil from supplier to facilities (base model)

Item	Selected facilities		
	Collection Bin		Plant
	Danurejan (j_1)	**Depok (J_2)**	
Facilities cost (day)	0	1099,8	0
Facilities allocation	0	1880	0

Item	Selected facilities		
	Collection Bin		Plant
	Danurejan (j_1)	Depok (J_2)	
Facilities cost	926,4	0	
Facilities allocation	681	0	

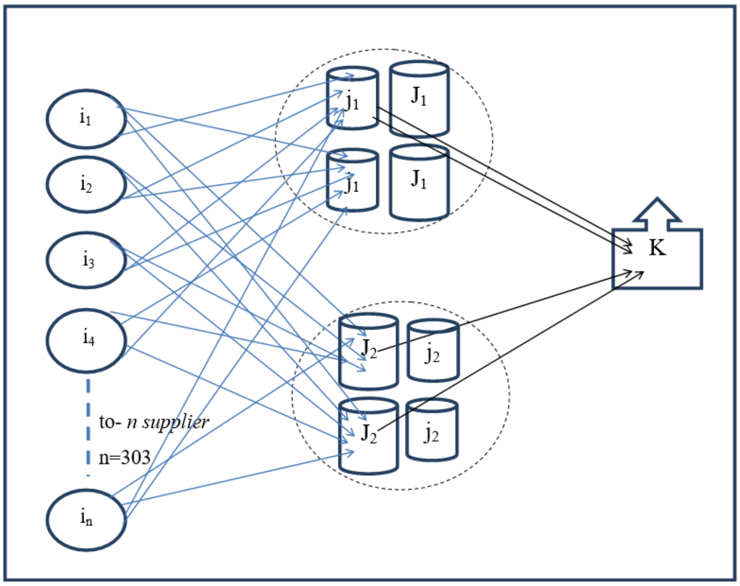

Figure 2. Optimized used cooking oil supply chain network (base model)

5.1 Sensitivity Analysis

Sensitivity analysis was conducted to examine the potential increase of used cooking oil. The increase in the amount of used cooking oil in 2025 is shown in Tables 3 and Table 4 and illustrated in Figure 3 as the following.

Table 3. Selected facilities (sensitivity model)

Item	Selected facilities		
	Collection Bin		Plant
	Danurejan (j_1)	Depok (J_2)	
Fixed cost (day)	1099,8	1099,8	1308441
Capacity of facilities	1880	1880	3000
Facilities selection	0	1	0
Fixed cost (day)	926,4	926,4	
Capacity of facilities	1320	1320	
Facilities selection	1	0	

Table 4. Flow of used cooking oil from supplier to facilities (sensitivity model)

Item	Selected facilities		Plant
	Collection Bin		
	Danurejan (j_1)	Depok (J_2)	
Facilities cost (day)	0	1099,8	0
Facilities allocation	0	1880	0
Facilities cost (day)	926,4	0	
Facilities allocation	900	0	

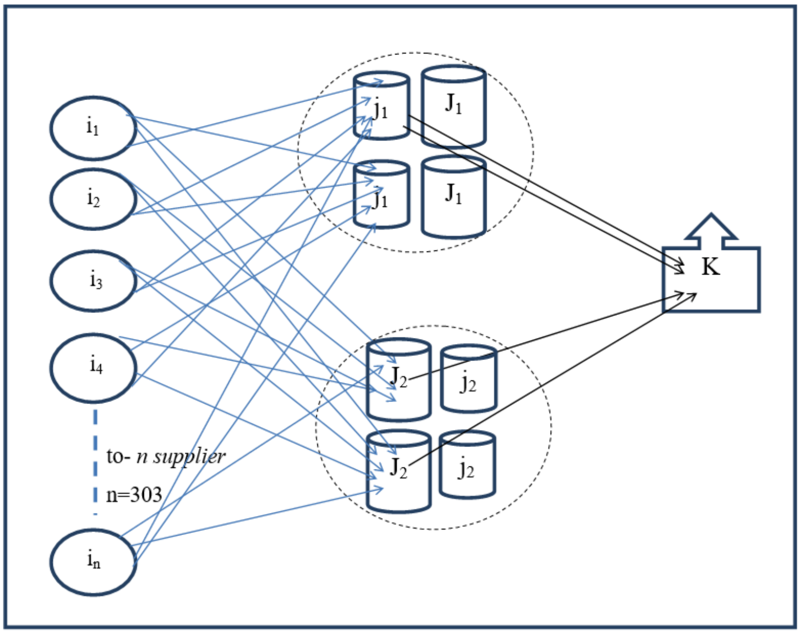

Figure 3. Optimized of used cooking oil supply chain network (sensitivity model)

6. Discussion

The present study was proposed a bioplant factory daily with an operating time of 300 days/year. The optimized supply chain design of the used-cooking oil supply chain network for basic model (Figure 2), from 2,561 litres of used cooking oil spread across several sub-districts in Yogyakarta. After optimization, it can be seen that the supplier source ***i*** is not directly transported to the biofuel plant but chooses several depots (Table 1), namely a depot with a small capacity in Danurejan j_1 and a depot with a medium capacity in Depok-Sleman J_2, to temporarily collect used cooking oil before being transported to the biofuel ***k*** plants. The allocation of the amount of used cooking oil (Table 2) in each depot is 681 litres in the Danurejan sub-district and 1880 litres in the Depok-Sleman sub-district. Based on the data processing, the transportation cost is IDR 750,615.40 per day, the depot procurement cost is IDR 2,026.2 per day, the vehicle purchase cost is IDR 7,836.80 and the investment cost is IDR 1,308.441.26, so the total cost incurred per day is IDR 3,047,279. Although the network model is optimal, the total supply of 2561 litres can only reach 14% of the total demand for biofuel as an alternative fuel in DIY.

The sensitivity analysis was conducted to evaluate the effect of the increase in used cooking oil for the next ten-year projection on the decision to open a facility for total cost minimization. Optimization of the used-cooking oil supply chain network for base model (Figure 3), from 2,780 litres of used cooking oil spread across several sub-districts in Yogyakarta. The allocation of the amount of used cooking oil (Table 4) at each depot is 900 litres at the Danurejan depot and 1880 litres at the Depok-Sleman depot. Based on the data processing, it is obtained that the transportation cost is IDR 760,896.50 depot procurement cost is IDR 2,026.2 per day, the vehicle purchase cost is IDR 7,837, and the investment cost is IDR 1,308.441, so the total cost incurred per day is IDR 3,033,330,55. The optimization results for the sensitivity model will affect the used-cooking oil supply chain network for the next ten years.

In this study, the used cooking oil supply network can be analyzed economically based on the distance between facilities and the cost of raw materials against transportation costs. If the price of used cooking oil raw materials is assumed to be IDR 3,500 and the farthest distance between facilities is from the source supplier to the depot of 66.8 km. Based on the research conducted, it can be seen that there are differences in decision variables for the base model and sensitivity model, as shown in Table 5. The difference between the base model and the sensitivity model is in the amount of used cooking oil distributed if the model is projected for 2025. This has an impact on the total cost generated.

Table 5. Comparison of base and sensitivity optimization model

Description	Base (IDR)	Sensitivity (IDR)
Total cost (day)	3.047.279,26	3.033.330,55
Transportation cost (day)	750.615,40	760.895,50
Vehicle Purchase cost (day)	7.836,80	7.836,80
The procurement cost of a depot for the small-scale (day)	926,40	926,40
The procurement cost of a depot for the medium-scale (day)	1.099,80	1.099,80
Investment cost of biofuel plant (day)	1.308.441,00	1.308.441,00

This study's feasibility analysis is the income-cost (R/C ratio) analysis. This analysis aims to determine the economic benefits by calculating the ratio between income and expenses (Kaparang, 2014). The costs used in this study are investment costs and operational costs. Investment costs are used to build installations, including factory construction, small depot procurement, and medium depot procurement costs. At the same time, operational costs are required by the factory to carry out production activities, such as purchasing raw materials and fuel costs for transportation. Based on the results of the calculation using the R/C ratio value> 1, it can be concluded that the investment is feasible because it provides a profit for daily production. Investment is possible because it allows for a profit for output per day.

7. Conclusion

This study models the used cooking oil supply network with 303 suppliers spread across districts in Yogyakarta, including data obtained from the food industry, catering, and fast food restaurants, which will produce a network map between the basic model and the sensitivity model. Meanwhile, for the primary model optimization results, no raw materials are directly sent to the biofuel plant but will be temporarily collected at several depots in each sub-district, namely depots in the Danurejan sub-district and the Depok-Sleman sub-district. After being collected at the depots, new raw materials will be sent to the biofuel plant. Likewise, for the optimization results for the sensitivity model, no raw materials are directly sent to the biofuel plant but will be collected first at depots in several sub-districts in DIY.

The mathematical model that was built resulted in 2 depots being decided to open, including a small depot in the Danurejan sub-district and a medium depot in the Depok-Sleman sub-district. The raw materials distributed are 681 litres to the Danurejan depot and 1880 litres to the Depok-Sleman depot. Meanwhile, sensitivity analysis of the increase in the amount of used cooking oil does not affect the decision to open depots but the number of raw materials distributed to each facility and the costs required for transportation, depot procurement, vehicle purchase, and factory construction so that the design of the used cooking oil supply network for biofuel in DIY that minimizes the total overall cost is IDR 3,047,280/day.

Because the present study is the first attempt at biofuel supply chain design, future research can be directed to evaluate the robustness of the model under various scenarios. Another future potential research is to implement the approach on higher and wider scale.

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