International Journal of Innovative Research and Scientific Studies, 8(2) 2025, pages: 1169-1182

IJIRSS International Journal of Innovative Research & Scientific Studies

ISSN: 2617-6548

URL: www.ijirss.com

Optimization of distribution network design product frozen food using linear programming

Probokusumo[1*], Endah Murtiana Sari[2], Karyadi[3], Galih Raspati[4], Yoki Muchsam[5]

[1,2,3,4,5]*Department of Industrial Engineering, Universitas Sains Indonesia, Bekasi, Jawa Barat 17530, Indonesia.*

Corresponding author: Probokusumo (*Email: probokusumo.p@lecturer.sains.ac.id*)

Abstract

Planning logistics costs that are effective and efficient is the goal of the company. Logistics costs need to be modeled through the demand occurring in the market so that the lowest and most efficient logistics cost scenario for the company can be found. This research aims to forecast the logistics costs of CV MIS, an organic food company that produces fresh and beneficial products by mixing antibiotic-free chicken, duck, and fish with probiotics or beneficial bacteria in animal feed and further processing. The consumer locations are scattered across various regions in Indonesia. Through a case study in this company, this research produces the lowest and most efficient scenario using the Mixed Integer Linear Programming (MILP) model, solved using the branch-and-bound technique on Lingo 20 software. The results of this study show that in the 20% demand scenario, the lowest total logistics cost is found in scenario 3 by opening one distribution center (DC) with a capacity of 7,500 Kg, specifically at DC(A), with a total cost of 2.3 billion IDR. In the 40% demand scenario, the lowest total logistics cost is found in scenario 6 by opening 1 DC with a capacity of 7,500 Kg precisely at DC(A) with a total cost of 2.3 billion IDR. In the 80% demand scenario, the lowest total logistics cost is found in scenario 9 by opening one DC with a capacity of 7,500 Kg exactly at DC(A) with a total cost of 2.3 billion IDR. Thus, the number and location of the chosen DC opening is in the Muara Sugihan area, by opening one DC with a capacity of 7,500 Kg. This research will be used as a basis for recommendations to open new routes in South Sumatra by CV Mina Indo Sejahtera, thus achieving effective and efficient logistics costs.

Keywords: Center of Gravity, Frozen Food, Linear Programming, Software Lingo, Supply Chain.

DOI: 10.53894/ijirss.v8i2.5421
Funding: This study received no specific financial support.
History: Received: 23 January 2025 / **Revised:** 27 February 2025 / **Accepted:** 10 March 2025 / **Published:** 14 March 2025

Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: Conceptualization, PK and EMS, methodology, PK, GR validation, EMS, PK, GR formal analysis PK, YM and EMS, investigations, EMS, K, YM data curation, EMS, GR and PK, writing—original draft preparation, EMS, YM, and PK, writing review and editing PK, EMS, GR, visualization, PK, supervision, K, YM project administration, PK, GR, K, YM All authors have read and agreed to the published version of the manuscript.
Transparency: The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.
Publisher: Innovative Research Publishing

1. Introduction

Frozen food is a food product that has been packaged and stored in a freezer so that it is ready to be cooked and consumed at a certain time [1]. CV Mina Indo Sejahtera is an organic food company that produces fresh and beneficial products by mixing antibiotic-free chicken, duck, and fish with probiotics or beneficial bacteria in animal feed and further processing. Some of the products produced by CV. Mina Indo Sejahtera (MIS) include marinated chicken, fresh chicken, marinated catfish, marinated tilapia, marinated gurami, marinated duck, chicken heads, chicken feet, and chicken gizzards. Processed foods do not contain monosodium glutamate (MSG), preservatives, or coloring agents, making them very safe to consume and also very practical and good for health.

CV. MIS is headquartered in Semarang and has several distributors, including Surabaya, Bandung, Brebes, Jakarta, Tegal, and Ungaran. Distribution is a very important process for producers' products to reach consumers effectively. The absence of a distributor in South Sumatra has resulted in the distribution process being less than optimal due to the long distance to the market. The overall sales data for CV. MIS products can be seen in Table 1. The data indicates that the demand in South Sumatra has not been fully met, as producers are only able to satisfy 80%, 40%, and 20% of the total demand. This results in products becoming spoiled by the time they reach the consumers. Producers are also unable to meet the overall demand due to many requests from other regions that have a lower risk of delays in product delivery [2].

The distribution process of products to South Sumatra is also more expensive due to the producers' locations being far from the markets in South Sumatra, where there are seven markets consisting of Musi Rawas, Banyuasin, Ogan Komering Ilir, Muara Enim, Lahat, Palembang, and Ogan Komering Ulu. The distribution cost data can be seen in Table 2.

Table 1.
Product Sales in South Sumatra.

No	Market	Phase	Demand	Product		
				Delivered	Until	Stale
1.	MR	1	3612	2830	2158	672
		2	3612	1412	986	426
		3	3612	706	586	120
2.	Banyuasin	1	5109	4060	3488	572
		2	5109	2016	1659	357
		3	5109	1007	782	225
3.	Ogan KI	1	2442	1904	1781	123
		2	2442	936	822	114
		3	2442	484	349	135
4.	ME	1	3276	2521	2046	475
		2	3276	1310	1108	202
		3	3276	653	481	172
5.	All	1	2550	2033	1721	312
		2	2550	1020	910	110
		3	2550	510	400	110
6.	Palembang	1	5985	4788	4109	679
		2	5985	2394	2032	362
		3	5985	1197	1045	152
7.	Ogan KU	1	2541	2031	1856	175
		2	2541	1013	758	255
		3	2541	507	385	122

Table 2.
Shipping Costs from Semarang to South Sumatra.

Recap	Quantity shipped/kg	Shipping cost/kg	Total Shipping Cost
Jan-24	750	IDR. 4.400.00	IDR. 3.300.000.00
Feb-24	975	IDR. 4.400.00	IDR. 4.290.000.00
Mar-24	834	IDR. 4.400.00	IDR. 3.669.600.00
Apr-24	717	IDR. 4.800.00	IDR. 3.441.600.00
May-24	978	IDR. 4.800.00	IDR. 4.694.400.00
Jun-24	1050	IDR. 4.800.00	IDR. 5.040.000.00
July-24	570	IDR. 5.200.00	IDR. 2.964.000.00
Aug-24	828	IDR. 5.200.00	IDR. 4.305.600.00
Sep-24	656	IDR. 5.200.00	IDR. 3.411.200.00
Oct-24	600	IDR. 5.600.00	IDR. 3.360.000.00
Nov-24	570	IDR. 5.600.00	IDR. 3.192.000.00
Dec-24	675	IDR. 5.600.00	IDR. 3.780.000.00

Table 1 shows the lack of fulfillment of product demand in the South Sumatra region this is due to many products becoming spoiled before reaching consumers, caused by delays from the shipping companies in delivering products, a lack of notification to consumers that the products have arrived, or the shipping companies not distinguishing that certain products need to be delivered immediately to consumers [3]. The recap of total shipping costs in January - December 2024 can be seen in Table 2 as follows:

Table 2 shows the distribution of total shipping costs over 1 year. The data shows that during the year June 2024, there was the highest cost with a total shipping amount of IDR. 5,040,000, while the lowest cost occurred in July 2024 with a total cost of IDR. 2,964,000. The high costs depend on the amount of demand being shipped because the shipping costs are based on the weight of the product in kg.

The problems faced when distributing Boemku products are that all parts of the distribution network for Boemku products are still not well integrated due to the absence of a Distribution Center (DC) connecting supply and demand [4]. This causes the demand for Boemku products to be uneven across regions; in some places, the supply of Boemku products exceeds demand, while in others, there is a shortage of supply. The distribution of Boemku products is still not organized and efficient, resulting in long distribution times and high shipping costs [5]. This makes the prices of Boemku products unstable, making them less affordable for all consumers in South Sumatra [6]. Business owners must have strategies to compete with competitors; strategies that can be implemented include optimizing the supply chain network [7]. According to Golestani, et al. [8], an optimally designed supply chain network has been proven to minimize the total supply chain costs, as 80% of supply chain costs are determined by the location of facilities and the flow of products between facilities in the supply chain. According to Comes, et al. [9], the design of the supply chain network is a combination of nodes with capabilities related to the paths that help raw materials or products move. Therefore, when designing the supply chain network, it is very important to consider the number and location of facilities such as factories, warehouses, and suppliers, as well as those that may open or close and have the capacity to be reallocated. With a well-designed and optimized supply chain network, it will enable smooth distribution, thus improving service to consumers. Once the network is designed, the next step is to maximize its performance so that products can reach consumers at the lowest possible cost [10].

Based on the background description above, to enhance the sales potential of CV. MIS, the owner and management of CV. MIS must always maintain and improve its performance, especially in terms of supply chain. The location of consumers scattered across various regions of Indonesia, particularly South Sumatra, makes the distribution costs of boemku products quite high. This presents a complex challenge for CV. MIS to serve all demands of consumers while keeping costs efficient [11]. Therefore, an optimal supply chain network design is needed for CV. MIS so that all consumers can still be served and ultimately with total supply chain costs that remain efficient.

2. Literature Review

2.1. Supply Chain Management

According to Chopra and Meindl [12] supply chain management is the management of the flow of goods and services and encompasses all processes that transform raw materials into finished products. It actively involves streamlining business activities on the supply side to maximize customer value and gain a competitive advantage in the market. Supply chain management consists of several stages including raw materials, supplier components, manufacturers, distributors, and customers.

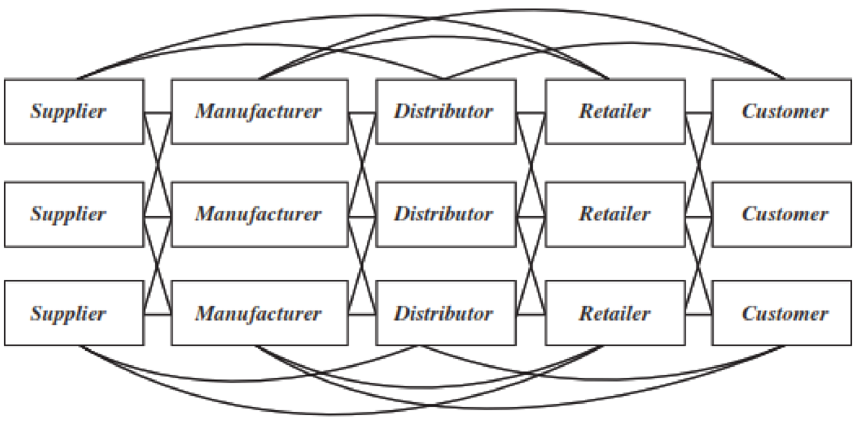


Figure 1.
Stages Supply Chain.
Source: Chopra and Meindl [12].

Figure 1 illustrates supply chain management is the management of the flow of goods and services and encompasses all processes that transform raw materials into finished products. It actively involves streamlining business activities on the supply side to maximize customer value and gain a competitive advantage in the market. Supply chain management consists of several stages including raw materials, supplier components, manufacturers, distributors, and customers.

In supply chain management, there are several factors to consider for different flows within the supply chain. Three phases are used to prepare for supply chain management, namely supply chain network design, supply chain planning, and supply chain operations control. Among these three steps, the design of the supply chain network is a very important decision, as it is a long-term strategic decision and requires significant costs to make changes. Issues related to this step include factory location, warehouse location, distribution center location, and supplier selection. Since network design is a strategic issue, changes to the network configuration are only made over a relatively long period, but network operations will continue [13]. Implementing a supply chain strategy is effective if the supply chain has a network with the right configuration. The network configuration can determine whether the supply chain can be responsive or efficient [14].

2.2. Network Design

The design of the supply chain network is a matter of several strategic decisions, such as determining the number, location, and capacity of facilities needed to meet consumer demand in a timely, efficient, and accurate manner [15]. When designing a supply chain network, consideration must be given to tentative decisions related to production, storage, distribution, transportation, and demand management (about to with concerning) as well as revenue and the required service levels. A significant portion of costs is incurred in supply chain management, particularly in certain distribution activities such as shipping and warehousing. One of the key questions at the strategic planning level is the design of the supply chain network and, more specifically, the search for the company's main facilities, such as factories and distribution centers [16]. Design decisions for the network can determine the configuration of the supply chain and significantly impact shipping costs and responsiveness Chopra and Meindl [12]. For example, the location of facilities has a lasting influence on the supply chain because it incurs high costs to relocate or open new facilities. While the costs of opening new facilities and combined inventory costs provide an incentive to reduce the number of facilities, responsiveness has the opposite effect. A high number of installations can reduce the time required to deliver products to the end consumer [17]. Distribution is the movement and storage of goods or products from suppliers to consumers within the supply chain network. Distribution is key to a company's profitability as it directly impacts supply chain costs and consumer demand. With an excellent distribution network, you can achieve various supply chain objectives, ranging from low-cost availability to high responsiveness in meeting consumer demand [18].

According to Zhang, et al. [19] transportation and distribution management is the management of the movement of products from one place to another, which forms a network. The role of the distribution and transportation network is very important. This distribution and transportation network enables the transportation of products from the place of production to the place of consumption. The ability to deliver products in the right quantity, in good condition, and on time to consumers determines whether the product is competitive enough in the market. Therefore, the ability to manage the distribution network is a very important competitive advantage for most industries.

According to Bai, et al. [20] consider several products involved in the design issues of distribution networks in a case study of the automotive industry. Based on practical assumptions, minimum volume, maximum distance, and confinement to a single source are introduced, making it a difficult problem to solve for large-scale cases. Therefore, they have developed several heuristic processes using various extensions of the MIP formula. Computer experiments analyze the structure of the generated network and the influence of various problem parameters on computation time. The results of this study show that the heuristic methods used can provide good solutions with short computation times.

According to Li, et al. [21] logistic problems often occur and are very important due to the shortage of raw material stocks in the production section that should always be available. Logistics play a fundamental role in the success of every supply chain, including the food supply chain. If production encounters constraints, it will disrupt the delivery schedule to consumers, resulting in poor service quality from the company. According to Ji, et al. [22] the selection of facility locations for a company is a crucial point in creating a more efficient distribution network. The problem of determining facility locations is very common, leading to transportation issues, and opening new facilities requires significant costs, resulting in a high number of facilities and increasing the lead time for goods to reach consumers.

2.3. Facility Location

Chopra and Meindl [12] describe the location of factories to find the locations of factories and warehouses simultaneously. When designing the supply chain network from suppliers to customers, a more general factory location model must be considered. Both factories and warehouses need to determine their locations and allocate capacity. Many camps can be used to meet market demand, and many factories can be used to fill the camps. This also assumes that units are properly arranged so that input units from supply sources produce finished product units. These models are:

2.4. Decision Variables

a. X_{ij} = The amount that must be distributed from start to finish

b. Y_i = Location selection for opening a DC

2. Purpose Function

a. Z(x) = Minimizing total distribution costs

$$\text{Min Z } = \sum_{i=1}^{n} (fiyi \, + \sum_{j=1}^{m} cij \, xij \,)$$

3. Constraints

a. $\sum_{i}^{n} \mathrm{xij} = \mathrm{Dj}, \forall \mathrm{j}$ constraint 1

b. $\sum_{i}^{m} xij \leq Kiyi, \forall i$ constraint 2
c. $X_{ij} \geq 0$ constraint 3
d. $Y_i \in \{0,1\}$ constraint 4

Description:
Constraint 1: units distributed = demand (demand is met)
Constraint 2: units distributed do not exceed capacity
Constraint 3: units distributed cannot be negative (0 or +)
Constraint 4: The decision variable Yi is binary
i = indicator reseller(1,2,3,….,n)
j = market/consumer indicator (1,2,3,…n)
Dj = demand from market j
Ki = plant capacity
fi= fixed cost (fixed cost)
cij = variable cost per unit i to j
yi = binary
xij = the volume sent from i to j

2.4. Center of Gravity

Center of Gravity (COG) is a method used to find alternative factory locations where total distribution (transportation) costs can be minimized. Specifically, the goal of the COG method is to minimize the total volume at a location multiplied by the average transportation cost rij for transporting goods from the origin to the endpoint (i to j) multiplied by the distance between locations i and j, with the formula [23].

$$Min. TC = \sum v_i r_{ij} d_{ij} \quad (1)$$

For example, (xi,yi) represents the coordinates of the starting point or base, and (xj,yj) represents the coordinates of the destination at several points. Thus, the distance *dj* can be calculated using the formula:

$$d_{ij} = \sqrt{(x_j - x_i)^2 + (y_j - y_i)^2} \quad (2)$$

If the location coordinates are in a geographic system consisting of latitude and longitude, then the calculation uses the Haversine formula as follows:

$$a = sin^2(\frac{\Delta\varphi}{2}) + cos\varphi_1 + cos\varphi_2 . sin^2(\frac{\Delta\lambda}{2}) \quad (3)$$

$$c = 2. \alpha. tan^2(\sqrt{\alpha}, \sqrt{(1-\alpha)}) \quad (4)$$

$$c = R. c \quad (5)$$

Where: φ = latitude
λ = longitude
R = Earth's radius (average radius = 6,371 kilometers)
To perform trigonometric functions, the angle value must be in radians (rad).

$$d = 2. r. sin^{-1}\left(\sqrt{sin^2(\frac{\varphi_1 - \varphi_2}{2}) + cos\,(\varphi_1). cos\,(\varphi_2). sin^2(\frac{\lambda_1 - \lambda_2}{2})}\right)$$

Optimal placement that can minimize total distribution costs can be done with the following steps:
1. For each starting and destination location, calculate dn using the formula above,
2. Calculate the new replacement position (x’,y’) using the formula:

$$x' = \frac{\sum_{n=1}^{k} \frac{DnCnXn}{dn}}{\sum_{n=1}^{k} \frac{DnCn}{dn}} \ldots\ldots\ldots (6) \qquad y' = \frac{\sum_{n=1}^{k} \frac{DnCnYn}{dn}}{\sum_{n=1}^{k} \frac{DnCn}{dn}} \ldots\ldots\ldots\ldots (7)$$

3. If the new location has the same coordinates as (x,y), then the iteration will stop; otherwise, update the location point values (x,y) = (x’,y’) and continue the next iteration starting from step one, and so on.
Various types of research related to supply chain network design, particularly regarding the layout of facility locations that can minimize distribution/transportation costs, have been conducted using the Center of Gravity model [24-27].

3. Materials and Method

This research uses a case study method on CV Mina Indo Sejahtera by simulating several scenarios that will later become the best choice to be implemented. Figure 2 shows the flowcharts of the research from the initial stage to the final stage, consisting of six stages: the introduction stage, the observation stage, the data collection stage, the data processing stage, the data analysis stage, and the conclusion stage, which are used to optimize the supply chain of frozen food products at CV Mina Indo Sejahtera. The first step in the data processing process is to determine the location of the opening of the distribution center using the center of gravity method. After the location is found, it is followed by processing using the linear programming method. The MILP model is processed using the software LINGO 20.0 to determine the quantity and where the distribution center will be opened. In summary, the methodology used in this study is as follows:

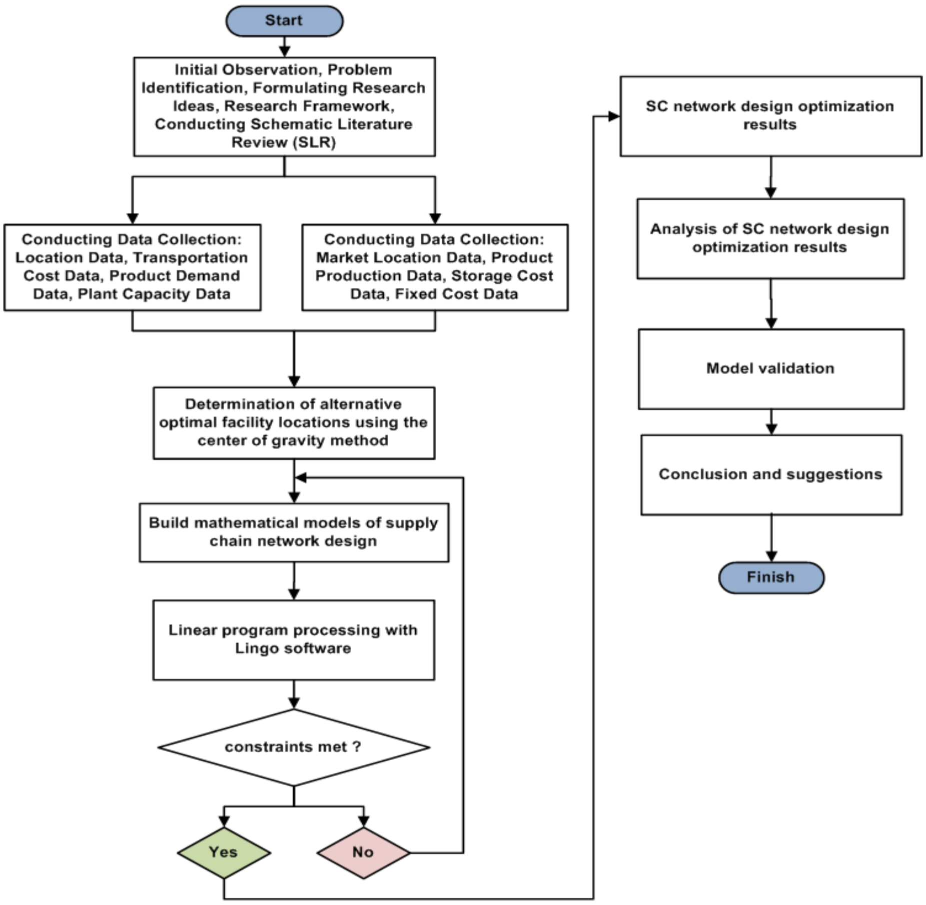


Figure 2.
Research design.

Figure 2 illustrates the stages of research that use scenarios to determine the sensitivity of the capacity of the distribution center (DC) that varies and selects the DC based on differences in capacity and fixed costs of the DC. Similarly, the fulfillment of consumer demand for Boemku products is divided into three parts, namely 20%, 40%, and 80% of the demand for Boemku products in South Sumatra. In this study, 100% of the demand data for Boemku products in South Sumatra is not used, as it refers to producers who do not only distribute products in South Sumatra but also throughout Indonesia.

Table 3.
Network Design Scenario.

Scenario	Request	DC Capacity (Kg)	Fixed Cost DC (IDR)
1	20 %	2.500	100.000.000
2		5.000	200.000.000
3		7.500	300.000.000
4	40%	2.500	100.000.000
5		5.000	200.000.000
6		7.500	300.000.000
7	80%	2.500	100.000.000
8		5.000	200.000.000
9		7.500	300.000.000

Table 3 the purpose of identifying the nine scenarios is to determine the sensitivity in selecting the DC due to increased capacity and fixed costs at different demand levels, thus achieving better results in determining the number and location of the DC [28].

4. Results

Center of Gravity (COG) is a method used to find alternative factory locations where total distribution (transportation) costs can be minimized. Specifically, the goal of the COG method is to minimize the total volume at a location multiplied by the average transportation cost rij for transporting goods from the origin to the endpoint (i to j) multiplied by the distance between locations i and j, with the formula [23, 29].

$$Min.TC = \sum v_i r_{ij} d_{ij} \quad (1)$$

For example, (xi,yi) represents the coordinates of the starting point or base, and (xj,yj) represents the coordinates of the destination at several points. Thus, the distance *dj* can be calculated using the formula:

$$d_{ij} = \sqrt{(x_j - x_i)^2 + (y_j - y_i)^2} \quad (2)$$

If the location coordinates are in a geographic system consisting of latitude and longitude, then the calculation uses the Haversine formula as follows:

$$a = sin^2(\frac{\Delta\varphi}{2}) + cos\varphi_1 + cos\varphi_2 . sin^2(\frac{\Delta\lambda}{2}) \quad (3)$$

$$c = 2.\alpha.tan^2(\sqrt{\alpha}, \sqrt{(1-\alpha)}) \quad (4)$$

$$c = R.c \quad (5)$$

Table 4.
Calculation format center of gravity adjusting.

Market	Location Coordinates		Distance (dn) (meters)	Demand (Dn)	Transportation Cost (/kg/KM) [Cn]	DnCnXn/dn	DnCnYn/dn	DnCn/dn
	Xn	Yn						
Palembang	1.047.630	-295.497		245	6.8			
Banyuasin	1.054.149	-332.777		164	6.7			
Musi Rawas	1.027.170	-270.620		118	5.6			
Ogan KI	1.074.084	-290.995		231	8.8			
Muara Enim	1.037.736	-365.961		159	7.2			
All	1.093.805	-688.259		114	10.8			
Ogan KU	1.066.658	-628.725		106	6.5			
TOTAL								

Where: φ = latitude
λ = longitude
R = Earth's radius (average radius = 6,371 kilometers)
To perform trigonometric functions, the angle value must be in radians (rad).

$$d = 2.r.sin^{-1}\left(\sqrt{sin^2(\frac{\varphi_1 - \varphi_2}{2}) + cos(\varphi_1).cos(\varphi_2).sin^2(\frac{\lambda_1 - \lambda_2}{2})}\right)$$

Then the next step is to calculate the distance between the starting point and the destination. Since the location uses geolocation format, the distance calculation is done using the Haversine formula, which would look like this when entered in Ms. Excel:

"=2*6371000*ASIN(SQRT((Lat2((*(3.14159/180)-Lat1*(3.14159/180))/2)) ^2 +COS(Lat2*(3.14159/180))*COS(Lat1*(3.14159/180))*SIN(((Long2*(3.14159/180)-Long1*(3.14159/180))/2)) ^2))"

Lat1 is the Latitude of the starting point (source) and Lat2 is the Latitude of the destination point (market), while Long1 is the Longitude of the starting point (source) and Long2 is the Longitude of the destination point (market).

Then, after obtaining the distance between the initial location point (x, y) and the destination point (xn, yn), the next step is to perform calculations aimed at obtaining alternative locations that are more optimal for placing the distribution center\, using the Center of Gravity Adjusting formula as follows:

$$x' = \frac{\sum_{n=1}^{k} \frac{DnCnXn}{dn}}{\sum_{n=1}^{k} \frac{DnCn}{dn}} \qquad y' = \frac{\sum_{n=1}^{k} \frac{DnCnYn}{dn}}{\sum_{n=1}^{k} \frac{DnCn}{dn}}$$

If the new location (x', y') has the same coordinates as (x, y), then the iteration will be stopped; otherwise, if they are not the same, update the values of the location point (x, y) to the values obtained from the latest alternative location (x', y') and continue the next iteration starting from the distance calculation step, and so on until the values are the same.

Based on the calculations that have been carried out until the values (x', y') are consistently the same as (x, y) (not experiencing changes shifts in coordinates), it is known that to obtain the optimal location for the distribution center, 18 iterations are needed with the result of the optimal location for the distribution center of CV. Mina Indo Sejahtera is at the geographic coordinates (105.76597; -3.47254). The calculation results of the Center of Gravity Adjusting for iteration 18 can be seen in Table 5.

Table 5.
Center of Gravity Adjusting Iteration 18.

Initial Delivery Location -->	X	105,41495
	Y	-3.3278

Market	Location Coordinates		Distance (dn) (meters)	Demand (Dn)	Transportation Cost (/kg/KM) [Cn]	DnCnXn /dn	DnCnYn/dn	DnCn /dn
	Xn	Yn						
Palembang	104.7630	-2.95497	83417	245	6.8	2.107484	-0.05944	0.0201
Banyuasin	105.4149	-3.32777	0	164	6.7	2736872	-863986	25963
Musi Rawas	102.7170	-2.70620	307450	118	5.6	0.222101	-0.00585	0.0022
Ogan KI	107.4084	-2.90995	226161	231	8.8	0.962337	-0.02607	0.0090
Muara Enim	103.7736	-3.65961	185872	159	7.2	0.636348	-0.02244	0.0061
All	109.3805	-6.88259	590824	114	10.8	0.228781	-0.01440	0.0021
Ogan KU	106.6658	-6.28725	357070	106	6.5	0.205616	-0.01212	0.0019
Total						2736879	-863987	25963

X’	105.41495
Y'	-3.3278

Table 4 and 5 describe the process before calculating the center of gravity until finding the best location at iteration 18. If a plot is made on the graph to see the positions of all players in the supply chain of CV. Mina Indo Sejahtera (including the selected distribution center), then a depiction like that in Figure 3 will be obtained.

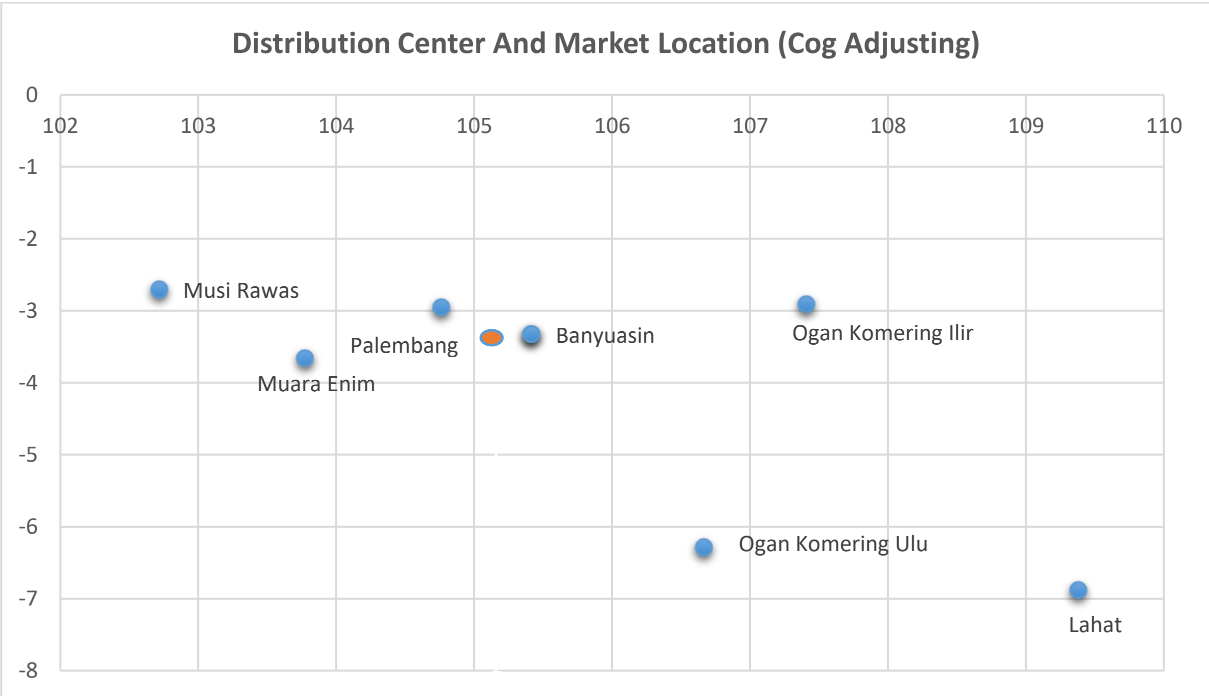


Figure 3.
Location Distribution Center and Market of CV. Mina Indo Sejahtera.
Source: Pinto, et al. [30]

The Linear Program will eventually be completed using the LINGO 20.0 application. Below is an example of the parameters for inputting data into the LINGO application for processing. The initial step in using the LINGO application is to determine the Model, Sets, and the data that will be entered. The Sets with the required attributes are plant, DC, Market, Time, and Product, with the data used for processing being capacity, production, demand, transportation costs, fixed costs, storage costs, and the percentage of demand. Next, data for each attribute must be entered. Then, after determining the data attributes, the objective function, and constraints, a display will appear as shown below, indicating that the model meets the requirements. It will then display results as shown in Figure 4. This figure is an example of one of the results from the processing in this research, which will be discussed in more detail in the following chapter.

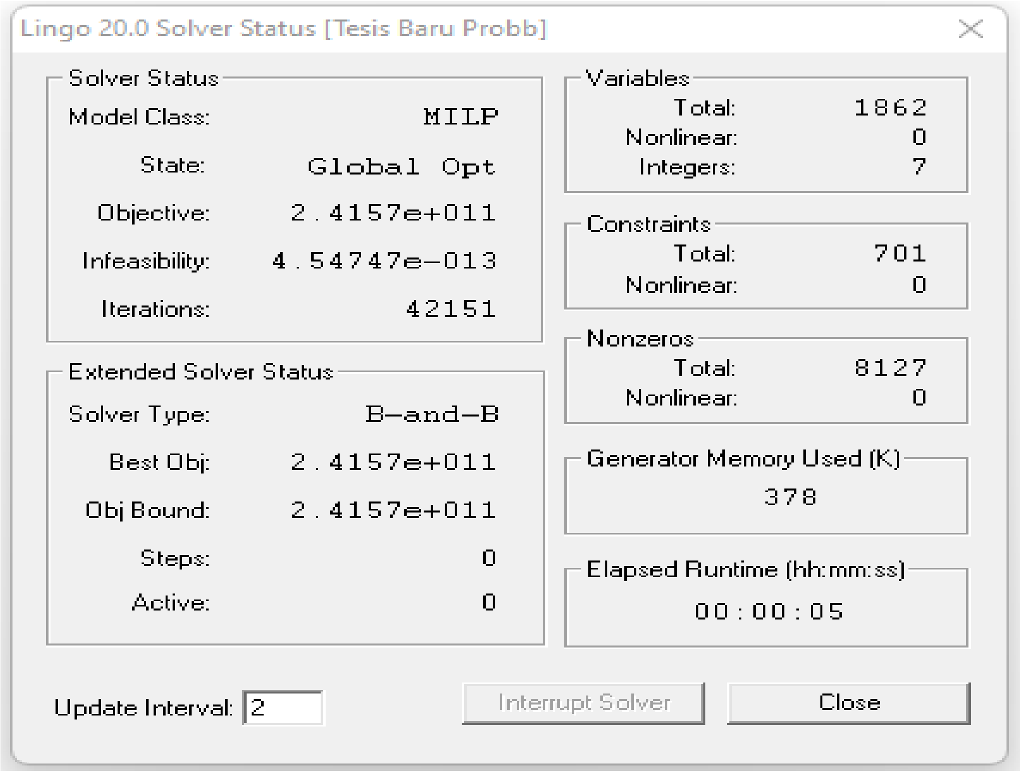
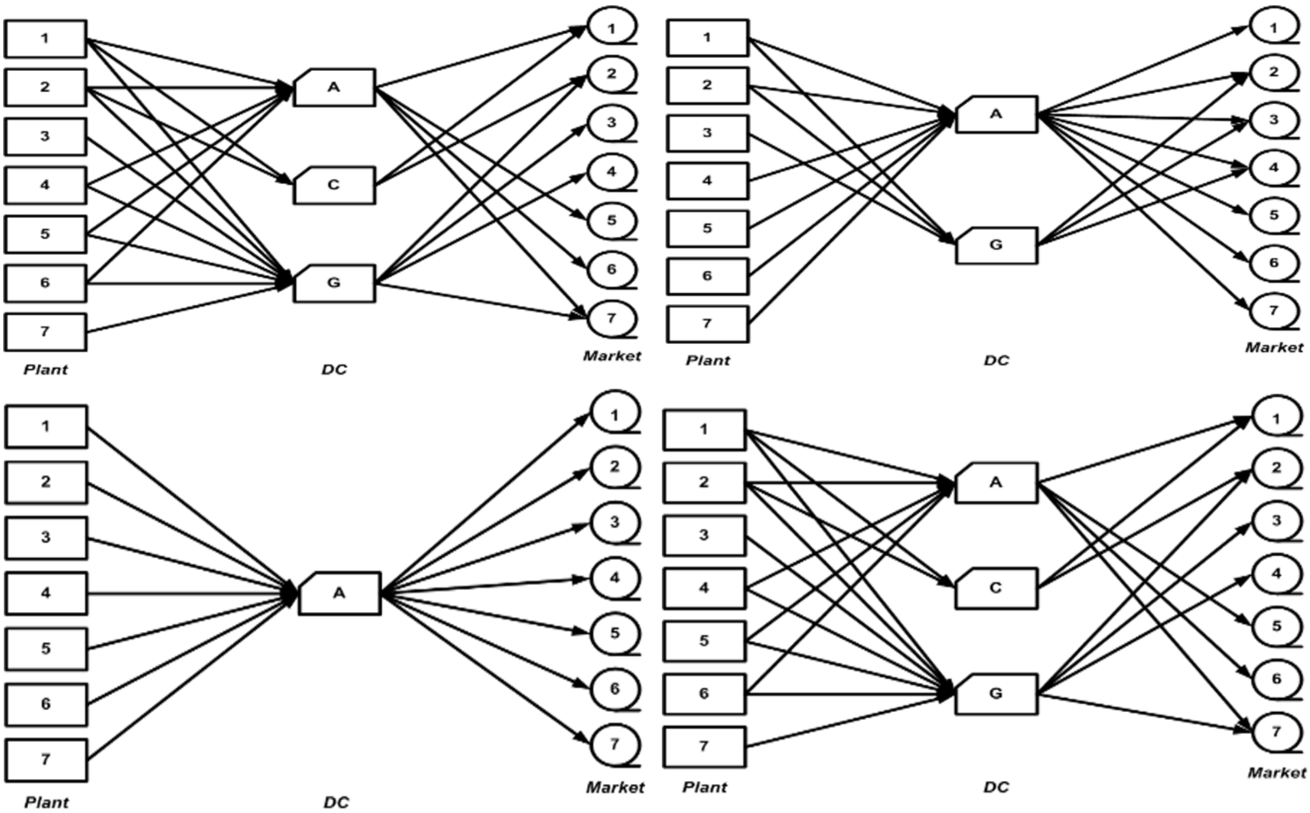


Figure 4.
Example Result Lingo.
Source: Deepa [23] and Pinto, et al. [30]

Figure 4 illustrates that LINGO is a software tool that is designed very broadly to solve operational research problems such as linear and nonlinear programming, quadratic model optimization, probability theory, and model optimization. The purpose of using the LINGO application is to find the optimal point and minimize shipping costs, thereby reducing transportation costs for CV. Mina Indo Sejahtera.



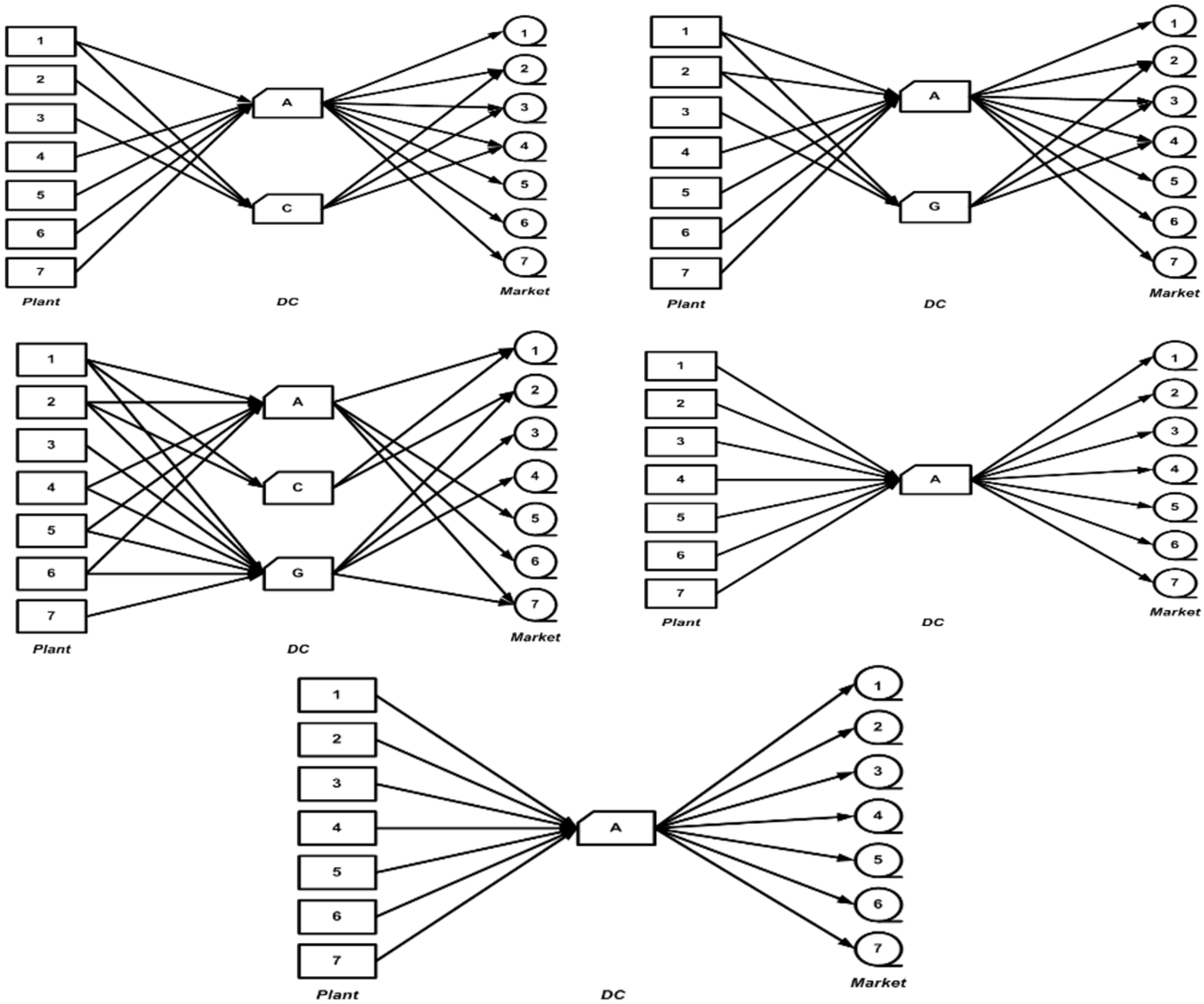


Figure 5.
Network Design Scenario 1- 9.

Figure 5 illustrates the results of the optimization results of the MILP model in nine scenarios as previously presented in the earlier chapter. The optimization process determines which DC should be selected and which DC should not be selected to achieve the most optimal value. Among the nine scenarios used to find the best solution to minimize the distribution costs used in this research.

5. Discussion

5.1. Analysis of Optimization Results

In this study, nine scenarios were used to optimize the supply chain design of Boemku products using the MILP model with LINGO 20 software. These nine scenarios have different dimensions, namely the required amounts and the capacity of the distribution center (DC), as explained in the previous chapter.

- In Scenario 1, with a total demand of 20% and a DC capacity of 2,500 kg, three DCs were opened with a total cost of IDR 2,366,940,000. Scenario 2, with a total demand of 20% and a DC capacity of 5,000 kg, will result in two DCs being opened with a total cost of IDR 2,349,790,000. Scenario 3, with a total demand of 20% and a DC capacity of 7,500 kg, results in one DC being opened with a total cost of IDR 2,340,230,000. The difference in total costs is due to the varying capacities of the DCs, with the fixed opening costs of the DCs differing. Meanwhile, transportation and storage costs remain the same as in the previous scenarios; a larger DC capacity leads to an increase in total distribution costs. Thus, it is evident that in scenarios (1 - 3) with the same demand of 20%, the lowest total distribution cost is found in Scenario 3 with a DC capacity of 7,500 kg.
- In scenario 4, with a total demand of 40% and a DC capacity of 2,500 Kg, three DCs are opened with a total cost of IDR 2,398,180,000. Scenario 5, with a total demand of 40% and a DC capacity of 5,000 Kg, will result in two open DCs with a total cost of IDR 2,371,940,000. Scenario 6, with a total demand of 40% and a DC capacity of 7,500 Kg, leads to the opening of one DC with a total cost of IDR 2,353,240,000. The difference in total costs is due to the varying capacities of the DCs and the different fixed costs of opening the DCs. Meanwhile, transportation and storage costs remain the same as in the previous scenarios; larger DC capacities lead to an increase in total distribution costs.

Thus, it can be seen that in scenarios 4 to 6, with the same demand of 40%, the lowest total distribution cost is found in scenario 6, which opens a DC with a capacity of 7,500 Kg.

- In scenario 7, with a total demand of 80% and a DC capacity of 2,500 Kg, three DCs were opened with a total cost of IDR 2,460,060,000. Scenario 8, with a total demand of 80% and a DC capacity of 5,000 Kg, resulted in the opening of two DCs with a total cost of IDR 2,415,700,000. Scenario 9, with a total demand of 80% and a DC capacity of 7,500 Kg, resulted in the opening of one DC with a total cost of IDR 2,379,240,000. The difference in total costs is due to the varying capacities of the DCs and the different fixed opening costs of the DCs. Meanwhile, transportation and storage costs remain the same as in the previous scenarios; larger DC capacities lead to an increase in total distribution costs. The details can be seen in Table 6.

Table 6.
Optimization Result.

Scenario	Request	DC Capacity (Kg)	DC Opening	Total Cost
1	20%	2.5	A. E. G	IDR. 2.366.940.000
2	20%	5	A. G	IDR. 2.349.790.000
3	20%	7.5	A	IDR. 2.340.230.000
4	40%	2.5	A. C. G	IDR. 2.398.180.000
5	40%	5	A. G	IDR. 2.371.940.000
6	40%	7.5	A	IDR. 2.353.240.000
7	80%	2.5	A. C. G	IDR. 2.460.006.000
8	80%	5	A. C	IDR. 2.415.700.000
9	80%	7.5	A	IDR. 2.379.240.000

Table 6 shows, it can be seen that in scenarios (7 - 9) with the same demand of 80%, the lowest total distribution cost is found in scenario 9, which opens a DC with a capacity of 7,500 Kg**.**

5.2. Analysis Before and After Optimization

With the establishment of a new distribution point for the new product, the total distance traveled to distribute the Boemku product to all market areas can be reduced to only 1,750,795 meters or 1,750 kilometers, and the total distribution cost of the product decreases to IDR 7,308,372,000. If expressed as a percentage, the result of the distance reduction after calculations with COG Adjusting is 60%, and the reduction in distribution costs for CV. MIS is 66%.

Table 7.
Recapitulation of Existing Supply Chain and COG Adjusting Results

	SC *Existing*	SC Adjusting
Location	Semarang	Banyuasin
Total distance traveled (KM)	4330.102288	1750.795516
Total Distribution Cost	IDR. 21.552.336.000	IDR. 7.308.372.000
Distance Savings	60%	
Cost Savings	66%	
Total Distance Traveled (meters)	4330102.29	1750795.52

Table 7 shows a summary of the results of minimizing the total distance traveled and total distribution costs obtained from calculations using the Haversine formula and the Center of Gravity Adjusting method.

5.3. Model Validation

The purpose of model validation is to determine whether the model used can provide reasonable solutions to the issues of DC capacity and location in the design of the Boemku product distribution network in South Sumatra. The validation approach is internal validation. This model validation employs internal validation by checking the integrity of the model against the desired conditions.

Verification is carried out by examining the results of the optimization. For example, the results of the optimization can be seen in Table 8 and 9 for a more detailed overall result of the optimization. First, determine the quantity of products shipped from the factory to the distribution center. This quantity is less than the capacity of the products produced by the factory. Next, determine whether the quantity of products shipped from the factory to the distribution center is greater than or equal to the quantity of products shipped from the distribution center to the consumers. Third, determine that the quantity of products sent to consumers is below the capacity of the distribution center. Fourth, the quantity of products sent from the distribution center matches consumer demand. Fifth, determine the inventory of the factory. This is the quantity of products produced in the initial inventory, minus the quantity of products shipped. Therefore, the model can be considered valid because the results of the optimization calculation checks above are the same. The results of the internal validation test indicate that the model is valid and can be used at the facilities in the problem location.

Table 8.
Results of Scenario 3 (Plant to DC).

Key	Phase	Product				
		Chicken	Duck	Catfish	Nila	Gurami
Plant-DC		(A)	(A)	(A)	(A)	(A)
1	1	0	0	0	2150	1252
	2	0	0	0	2764	2398
	3	0	0	0	0	875
2	1	3358	3596	1382	0	0
	2	5633	2872	4946	0	0
	3	1382	4330	4471	0	0
3	1	0	0	0	0	0
	2	0	0	0	0	0
	3	0	0	0	0	0
4	1	2274	0	1825	3240	0
	2	0	0	1656	2160	0
	3	4250	0	2132	5390	0
5	1	0	0	3395	0	3661
	2	0	0	0	0	2808
	3	0	0	0	0	4330
6	1	0	292	0	0	0
	2	465	0	0	0	0
	3	0	0	0	0	0
7	1	0	1920	0	0	0
	2	0	2643	0	0	0
	3	0	1185	0	0	0

Table 9 shows the results of the scenario from the factory to DC to validate the results of the latest optimization model. From the example table is the result of model verification in the third scenario, it can be seen that the model is valid because when applied to the lingo software it shows the same results where the results indicate that this optimization model is successful and tested. The results of the DC to market scenario are shown in Table 9:

Table 9.
Results of Scenario 3 (DC to Market).

Product					Phase	Key
Chicken	Duck	Catfish	Nila	Gurami		
(A)	(A)	(A)	(A)	(A)		DC - Market
750	675	834	636	717	1	1
750	675	834	636	717	2	
750	675	834	636	717	3	
1050	975	1080	1026	978	1	2
1050	975	1080	1026	978	2	
1050	975	1080	1026	978	3	
450	600	615	300	477	1	3
450	600	615	300	477	2	
450	600	615	300	477	3	
675	600	828	618	555	1	4
675	600	828	618	555	2	
675	600	828	618	555	3	
375	498	636	648	393	1	5
375	498	636	648	393	2	
375	498	636	648	393	3	
1200	1017	1350	1293	1125	1	6
1200	1017	1350	1293	1125	2	
1200	1017	1350	1293	1125	3	
570	600	600	330	441	1	7
570	600	600	330	441	2	
570	600	600	330	441	3	

Table 9 shows the results of the scenario from DC to market to validate the results of the latest optimization model. From the example table is the result of model verification in the third scenario, it can be seen that the model is valid because when applied to the lingo software it shows the same results where the results indicate that this optimization model is successful and tested.

6. Conclusions

From the research presentation above, the following can be concluded:

1. This model takes into account the uncertainty of product supply and can be used to design the distribution network for Boemku products. Thus, inventory is needed at the factory and distribution center area to meet the entire demand in South Sumatra.
2. This research used nine scenarios where each scenario has a different quantity, both in terms of demand and DC capacity. The results of this study show that with a DC capacity of 2,500 Kg, at a demand of 20%, three DCs are opened; at a demand of 40%, three DCs are opened; and at a demand of 80%, three DCs are opened. With a DC capacity of 5,000 Kg, at demands of 20%, 40%, and 80%, two DCs are opened. Meanwhile, with a DC capacity of 7,500 Kg, in all demand scenarios of 20%, 40%, and 80%, one DC is opened. In the 20% demand scenario, the total logistics cost is lowest in scenario 3 by opening one DC with a capacity of 7,500 Kg, specifically at DC (A) with a total cost of IDR 2,340,230,000. In the 40% demand scenario, the total logistics cost is lowest in scenario 6 by opening one DC with a capacity of 7,500 Kg, specifically at DC (A) with a total cost of IDR 2,353,240,000. In the 80% demand scenario, the total logistics cost is lowest in scenario 9 by opening one DC with a capacity of 7,500 Kg, specifically at DC (A) with a total cost of IDR 2,379,240,000. Therefore, for the selected quantity and location, the opening of the DC is located in the area (A) Muara Sugihan, with one DC opened with a capacity of 7,500 Kg.
3. In this study, three periods within one year are used, namely period 1 (January-April), period 2 (May-August), and period 3 (September-December). The determination of these periods is based on the production data of the boemku product above, which comes from CV. Mina Indo Sejahtera. Thus, it is assumed that the production and demand periods are the same, which is three periods. In reality, the production and demand periods for the boemku product are not the same. Therefore, in future research, a greater variety of periods could be used to better approximate real conditions and yield more accurate results. The fixed costs of opening a distribution center (DC) are based on the cost level according to the capacity of the DC, assuming that the DC capacity and fixed costs increase linearly. In reality, the costs and capacities of the DC will not be the same at each location. If this model is applied by parties involved in the distribution field, original data from the relevant parties is needed so that the results can be better and closer to real conditions. In this study, the capacity of the DC at all locations is considered the same, whereas, in reality, it may vary depending on the capability and needs at each DC opening location. For this model to be improved, it is necessary to develop it using different DC capacities at each location.

References

[1] B. Castelein, H. Geerlings, and R. Van Duin, "Cold chain strategies for seaports. Towards a worldwide policy classification and analysis," *European Journal of Transport and Infrastructure Research,* vol. 20, no. 3, pp. 1-28, 2020. https://doi.org/10.18757/ejtir.2020.20.3.4074

[2] W. Wu, C. Beretta, P. Cronje, S. Hellweg, and T. Defraeye, "Environmental trade-offs in fresh-fruit cold chains by combining virtual cold chains with life cycle assessment," *Applied Energy,* vol. 254, p. 113586, 2019. https://doi.org/10.1016/j.apenergy.2019.113586

[3] F. Qiu *et al.*, "A novel multi-objective model for the cold chain logistics considering multiple effects," *Sustainability,* vol. 12, no. 19, p. 8068, 2020. https://doi.org/10.3390/su12198068

[4] S. K. Mangla, Y. K. Sharma, P. P. Patil, G. Yadav, and J. Xu, "Logistics and distribution challenges to managing operations for corporate sustainability: study on leading Indian diary organizations," *Journal of Cleaner Production,* vol. 238, p. 117620, 2019. https://doi.org/10.1016/j.jclepro.2019.117620

[5] G. Liu, J. Hu, Y. Yang, S. Xia, and M. K. Lim, "Vehicle routing problem in cold Chain logistics: A joint distribution model with carbon trading mechanisms," *Resources, Conservation and Recycling,* vol. 156, p. 104715, 2020. https://doi.org/10.1016/j.resconrec.2020.104715

[6] Z. Liu *et al.*, "Research on the optimized route of cold chain logistics transportation of fresh products in context of energy-saving and emission reduction," *Mathematical Biosciences and Engineering,* vol. 18, no. 2, pp. 1926-1940, 2021. https://doi.org/10.3934/MBE.20210100

[7] R. Arivalagan, "Logistics network optimization in distributing critical medical supplies for a pharmaceutical company," *International Journal of Recent Technology and Engineering,* vol. 8, no. 3, pp. 7767-7770, 2019. https://doi.org/10.35940/ijrte.C6320.098319

[8] M. Golestani, S. H. Moosavirad, Y. Asadi, and S. Biglari, "A multi-objective green hub location problem with multi item-multi temperature joint distribution for perishable products in cold supply chain," *Sustainable Production and Consumption,* vol. 27, pp. 1183-1194, 2021. https://doi.org/10.1016/j.spc.2021.02.026

[9] T. Comes, K. Bergtora Sandvik, and B. Van de Walle, "Cold chains, interrupted: The use of technology and information for decisions that keep humanitarian vaccines cool," *Journal of Humanitarian Logistics and Supply Chain Management,* vol. 8, no. 1, pp. 49-69, 2018. https://doi.org/10.1108/JHLSCM-03-2017-0006

[10] M. Hariga, R. As' ad, and A. Shamayleh, "Integrated economic and environmental models for a multi stage cold supply chain under carbon tax regulation," *Journal of Cleaner Production,* vol. 166, pp. 1357-1371, 2017. https://doi.org/10.1016/j.jclepro.2017.08.105

[11] A. Diaz, J.-P. Schöggl, T. Reyes, and R. J. Baumgartner, "Sustainable product development in a circular economy: Implications for products, actors, decision-making support and lifecycle information management," *Sustainable Production and Consumption,* vol. 26, pp. 1031-1045, 2021. https://doi.org/10.1016/j.spc.2020.12.044

[12] S. Chopra and P. Meindl, *Supply chain management: Strategy, planning, and operation*, 6th ed. Upper Saddle River, NJ: Pearson Education, Inc, 2016.

[13] A. Gallo, R. Accorsi, G. Baruffaldi, and R. Manzini, "Designing sustainable cold chains for long-range food distribution: Energy-effective corridors on the Silk Road Belt," *Sustainability*, vol. 9, no. 11, p. 2044, 2017. https://doi.org/10.3390/su9112044

[14] L. D. Burns, R. W. Hall, D. E. Blumenfeld, and C. F. Daganzo, "Distribution strategies that minimize transportation and inventory costs," *Operations Research*, vol. 33, no. 3, pp. 469-490, 1985. https://doi.org/10.1287/opre.33.3.469

[15] E. Bottani, G. Casella, M. Nobili, and L. Tebaldi, "Assessment of the economic and environmental sustainability of a food cold supply chain," *IFAC-PapersOnLine*, vol. 52, no. 13, pp. 367-372, 2019. https://doi.org/10.1016/j.ifacol.2019.11.150

[16] R. K. Singh, A. Gunasekaran, and P. Kumar, "Third party logistics (3PL) selection for cold chain management: A fuzzy AHP and fuzzy TOPSIS approach," *Annals of Operations Research*, vol. 267, pp. 531-553, 2018. https://doi.org/10.1007/s10479-017-2591-3

[17] P. Engelseth and N. P. Kvadsheim, "Conceptual modelling of upstream offshore seaweed supply," *International Journal of Design and Nature and Ecodynamics*, vol. 12, no. 4, pp. 516–524, 2017. https://doi.org/10.2495/DNE-V12-N4-516-524

[18] L. Wang *et al.*, "Broadband vibration energy harvesting for wireless sensor node power supply in train container," *Review of Scientific Instruments*, vol. 90, no. 12, p. 125003, 2019. https://doi.org/10.1063/1.5127243

[19] L.-Y. Zhang, M.-L. Tseng, C.-H. Wang, C. Xiao, and T. Fei, "Low-carbon cold chain logistics using ribonucleic acid-ant colony optimization algorithm," *Journal of Cleaner Production*, vol. 233, pp. 169-180, 2019. https://doi.org/10.1016/j.jclepro.2019.05.306

[20] L. Bai, X. Chen, J. Sun, and X. Zhang, "Development of potato processing industry in China from perspective of industrial integration," *Transactions of the Chinese Society of Agricultural Engineering*, vol. 35, no. 8, pp. 316–323, 2019. https://doi.org/10.11975/j.issn.1002-6819.2019.08.037

[21] H. Li, T. Wu, J. Ran, J. Zhan, and Y. Zhu, "Spatial coupling between specialized production of fruits and vegetables and front-end cold-chain logistics," *International Journal of Design & Nature and Ecodynamics*, vol. 15, no. 2, pp. 167-176, 2020. https://doi.org/10.18280/ijdne.150205

[22] Y. Ji, J. Du, X. Wu, Z. Wu, D. Qu, and D. Yang, "Robust optimization approach to two-echelon agricultural cold chain logistics considering carbon emission and stochastic demand," *Environment, Development and Sustainability*, pp. 1-24, 2021. https://doi.org/10.1007/s10668-021-01236-z

[23] S. Deepa, "Solving supply chain network optimization models using LINGO. Research India Publications," Retrieved: http://www.ripublication.com, 2015.

[24] G. Zhang, G. Li, and J. Peng, "Risk assessment and monitoring of green logistics for fresh produce based on a support vector machine," *Sustainability*, vol. 12, no. 18, p. 7569, 2020. https://doi.org/10.3390/su12187569

[25] L. Leng, C. Zhang, Y. Zhao, W. Wang, J. Zhang, and G. Li, "Biobjective low-carbon location-routing problem for cold chain logistics: Formulation and heuristic approaches," *Journal of Cleaner Production*, vol. 273, p. 122801, 2020. https://doi.org/10.1016/j.jclepro.2020.122801

[26] Y. Zhang, L. Zhao, and C. Qian, "Modeling of an IoT-enabled supply chain for perishable food with two-echelon supply hubs," *Industrial Management & Data Systems*, vol. 117, no. 9, pp. 1890-1905, 2017. https://doi.org/10.1108/IMDS-10-2016-0456

[27] P. Danese, R. Mocellin, and P. Romano, "Designing blockchain systems to prevent counterfeiting in wine supply chains: A multiple-case study," *International Journal of Operations & Production Management*, vol. 41, no. 13, pp. 1-33, 2021. https://doi.org/10.1108/IJOPM-12-2019-0781

[28] A. Mohammed, Q. Wang, and X. Li, "A cost-effective decision-making algorithm for an RFID-enabled HMSC network design: A multi-objective approach," *Industrial Management & Data Systems*, vol. 117, no. 9, pp. 1782-1799, 2017. https://doi.org/10.1108/IMDS-02-2016-0074

[29] R. Zhong, X. Xu, and L. Wang, "Food supply chain management: Systems, implementations, and future research," *Industrial Management & Data Systems*, vol. 117, no. 9, pp. 2085-2114, 2017. https://doi.org/10.1108/IMDS-09-2016-0391

[30] N. M. Pinto, C. Lopez Del Puerto, and H. D. Jeong, "Development of a partnering maturity assessment tool for transportation agencies," *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, vol. 10, no. 4, p. 04518021, 2018. https://doi.org/10.1061/(asce)la.1943-4170.0000272