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Distribution Model for Mobile Phone Products in The South Sumatra Region Using Croston Method and MILP

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Abstract
MEI has approximately ten Stores spread across South Sumatra, which are supplied by three Distribution Centers, namely DC Palembang, DC Jambi, and DC Bengkulu. In its distribution, the constraints are the distance between several shipments to each store, which takes a long time and costs a lot of money. Based on these conditions, the purpose of this study is to balance the supply volume and determine the optimal route. For this study, forecasting will be carried out using the ARIMA and Croston methods because of the sporadic sales level. Furthermore, optimization of the DC supply location points and supply volume is carried out using linear programming, and the best route is determined using mixed integer linear programming with the Northwest Corner method. The forecasting results are used to predict the total supply load at three depots in the South Sumatra region; then, the supply volume is determined using linear programming. It is known that the Store locations that DC Palembang will supply are Muara Enim, Pagar Alam, Banyuasin, and Lahat. DC Jambi will supply Bungo, Batang Hari, and Kerinci Stores, while DC Bengkulu, which previously only supplied 2 Stores, now has 4 Stores, including Pagar Alam, Lubuk Linggau, Lebong, and Kepahiang. Based on the regional transportation model of South Sumatra, transportation costs can be minimized by up to 21%.

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1. Introduction

Maju Express Indonesia (MEI) is a company that provides mobile phone products and is the official distributor of the Realme brand. In its logistics activities, MEI has approximately 10 branches spread throughout Indonesia. So, the central warehouse for distributing products from manufacturers must always monitor the availability of Realme cellphone products in branch warehouses so that there is no shortage of ready stock, which causes the company to lose sales momentum; the sales condition can be seen in Figure 1 below. In its logistics activities, MEI experienced several problems, namely problems related to transportation and product distribution from the depot to several stores in different locations. Apart from that, problems also occur on delivery routes that are quite far away, so they take quite a long time and cause delays in the delivery process. The location of each store that must be supplied by each depot in the South Sumatra area is in different cities and quite far away, so this requires the right and optimal strategy so that the route traveled by the driver is in the most optimal condition. So that there is no delay in delivery. MEI is advised to plan and control supply volumes and determine route distribution routes at optimal levels. To help with logistics activities, a method or idea is needed that can organize and control the flow of products and information effectively and efficiently from the supply chain, namely logistics management. The target to be achieved in this research is to increase the efficiency of determining supply volume by determining the right forecasting method and optimizing product distribution activities from 3 depots in the South Sumatra area to 10 Stores located in several cities in South Sumatra using the mixed integer method linear programming.

Previous research on logistics distribution has been widely carried out [1] conducted research on the distribution of beef with two depots using MDVRP [2], the results obtained were the best route and the lowest cost. [3] This article investigates the multidepot vehicle routing problem (MDVRP), which involves optimizing vehicle routes across multiple depots. Researchers have applied the artificial bee colony (ABC) algorithm to address the MDVRP, conducting thorough experiments with various parameters. They compared the performance of the ABC algorithm with that of the greedy algorithm and the genetic algorithm (GA). The results demonstrate that the ABC algorithm exhibits strong performance. [4] Research is being done to optimize distribution channels by considering how carbon emissions can reduce distribution costs for logistics companies. [5] Research to ensure optimal distribution channels for Bingo LLC end products by applying a multifaceted decision-making framework combining the Full Consistency Method (FUCOM) and the Measurement of Alternatives and Ranking by Compromise Solutions (MARCOS) methodology. This study is evidence of the application of decision-making models in operational improvement and contributes to existing knowledge with empirical evidence from the case of Bingo LLC. In contrast to previous research, this research designs a distribution model for several regions in Sumatra, which have 3 depots to serve Stores in more than 6 cities. This research will obtain the best route, cheapest, and most efficient transportation costs. This research will reduce distribution costs and increase product distribution performance.

2. Material and method

The distribution and logistics industries are essential to maintaining effective supply chain operations, especially in geographically scattered areas [6]. Distribution networks are optimized using various techniques to save expenses and raise service standards. This section examines pertinent research on mixed-integer linear programming for route determination, linear programming for supply optimization, and demand forecasting [7]. The focus is forecasting techniques for intermittent demand scenarios, such as ARIMA and Croston's approach.

Demand forecasting is a crucial part of supply chain management, which helps businesses anticipate future demand and maximize inventory levels. Chopra and Meindl (2019) assert that precise demand forecasting can enhance supply chain efficiency by minimizing stockouts and reducing surplus inventory. Various forecasting techniques have been used to predict future demand patterns, including machine learning, regression models, and time-series analysis [8, 9].

A popular statistical model for time-series forecasting, ARIMA works especially well when data shows temporal connections. To address trends and seasonality in demand patterns, the model—first presented by Box and Jenkins in 19—combines autoregressive (AR), differencing (I), and moving average (MA) components. According to studies by Makridakis *et al*. (1998), ARIMA is a recommended strategy in logistics for steady and predictable demand situations because of its accuracy in short—to medium-term forecasting [10].

Traditional forecasting techniques, such as ARIMA, might not work well for supply chains dealing with erratic or intermittent demand. This problem is explicitly addressed by Croston's technique (1972), which estimates the demand size and the period between demand occurrences independently. This method is well known for its capacity to lessen forecast bias in situations involving sporadic demand, such as the logistics of spare parts and infrequent product delivery [11].

A mathematical method called linear programming (LP) is used to maximize resource allocation while considering cost, demand, and capacity limitations. The efficiency of LP in distributing supply amounts among distribution hubs is highlighted by Gass and Harris (2000). LP models are especially helpful for multi-facility supply chains in figuring out how to distribute commodities to reduce holding and transportation expenses. The use of LP to reduce supply network inefficiencies and provide notable cost reductions is also highlighted in studies by Dantzig (1963).

A sophisticated optimization technique called mixed-integer linear programming (MILP) combines continuous and binary variables to address challenging logistical issues like network architecture and truck routing. [12] Explain how MILP is used in transportation models to identify the most economical routes while considering delivery windows and vehicle capacity. Case studies in regional logistics planning show how MILP has been applied to lower transportation costs and speed up delivery [7].

One of the main goals of logistics research has been to lower transportation costs. It has been demonstrated that models that combine forecasting, LP, and MILP efficiently reduce expenses. [13] For instance, optimization studies were conducted that improved route efficiency and balanced supply loads to reduce costs. Furthermore, regional logistics frameworks in developing nations demonstrate that adding geographic and regional factors to transportation models can result in significant cost savings [2, 14].

One essential strategy for resolving transportation-related issues in operations research is the Northwest Corner Method (NWC) [15]. Its main purpose is to produce a preliminary solution for distribution issues with the goal of reducing transportation expenses. It is a common starting point because of its simplicity and convenience of use, even if it does not ensure optimality [16].

Starting from the top-left (northwest) corner of the transportation table, the approach allocates shipments row by row or column by column until supply and demand constraints are satisfied. The Northwest Corner approach is frequently used for teaching reasons and as a basis for additional optimization utilizing strategies like the Modified Distribution (MODI) approach, despite its drawbacks, which include neglecting transportation costs during allocation and frequently producing inferior results. Its use extends beyond logistics [7].

This research aims to minimize shipping costs and determine the best route model to minimize product delivery delays. The first step to take is to determine the appropriate forecasting model using Rstudio software for mobile phone demand at each store in the South Sumatra area to determine the supply volume at each store, then determine the distribution model using the mixed integer linear programming method for each store in the South Sumatra area. [17, 2,18,19] In this research, forecasting was carried out using two methods, namely Croston and ARIMA, and also using a method developed by J. D. Croston in 1972. This method develops the exponential smoothing method to predict the number of requests and the time interval between requests (Intermittent Demand) [20]. The Autoregressive

Integrated Moving Average (ARIMA) method is a method that completely ignores independent variables to determine forecasting [9]. ARIMA uses previous and current data based on dependent variables to obtain accurate short-term forecasting.

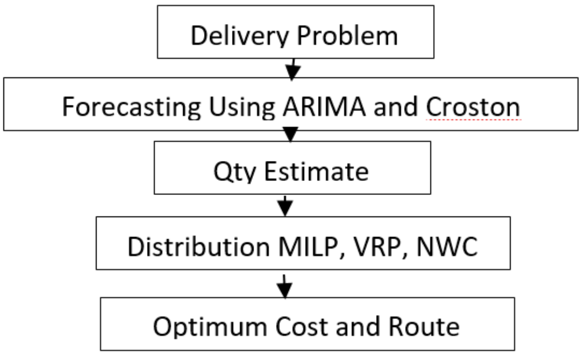

Fig 1: Research Flow

The next step is to optimize the distribution route using Linear programming [21–25]. Mixed integer linear programming (MILP) represents an effective mathematical modeling approach to solve complex optimization tasks and identify potential trade-offs between conflicting objectives [26], which can provide a better understanding of bioenergy systems and support decision makers in deciphering pathways sustainable towards bioenergy targets. Vehicle Routing Problem (VRP) is a complex combinatorial optimization problem used to solve the problem of determining delivery routes by a fleet to serve one or more company customers based on one or more existing depots [27]. Several restrictions must not be violated, such as the fleet cannot carry products that exceed the fleet's capacity, the fleet cannot pass routes other than those that have been determined, and the services provided to customers must be within a certain time frame that has been determined. Multi-depot VRP is a VRP with the problem of companies having various depots spread around the customer's location [28].

Result

The initial stage of this research was to collect data related to logistics process activities, namely the distribution process of HP products from the Central DC to the South Sumatra area depot. Then, from the depot, the products were supplied to a Store in the South Sumatra area.

This research was conducted to analyze the distribution activities carried out by MEI from Central DC to stores in the South Sumatra area to balance demand and supply and minimize transportation costs. The stages carried out in this research are Forecasting, Transportation Method (linear programming), Classification of Depot area supply, and multi-depot Vehicle Routing Problem (VRP) with mixed integer linear programming.

3.1 Forecasting demand for each store

Forecasting aims to estimate demand for HP products in the future. Forecasting in this research was carried out for demand at 10 Stores in the South Sumatra area for the next 1 month because if the forecasting were carried out over a long period, then the accuracy of the forecasting results would be considered less accurate. This research determined forecasting by conducting experiments with the Croston and the seasonal ARIMA methods. The results of this forecasting value will later become distribution needs that the depot must supply for each store. The forecasting determination in this research was carried out using the RStudio software. Forecasting calculations were carried out for 10 branches using the Croston and Arima methods; this was used to get the best model, considering that shipping showed unstable data.

The initial stage is to examine the demand trend from Muara Enim Store in January 2023, which is shown in Figure 1 below.

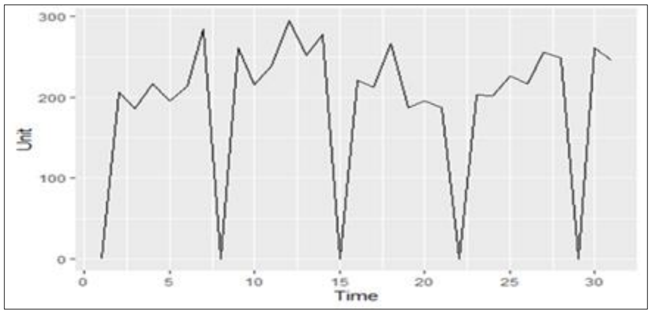

Fig 2: Muara Enim Store Demand Graph

Judging from the demand trend, there is intermittent demand in 5 certain periods, so forecasting is carried out using the Croston method to estimate intermittent demand for HP products. After determining forecasting using the Croston method, the residual graph shown in the image below is obtained.

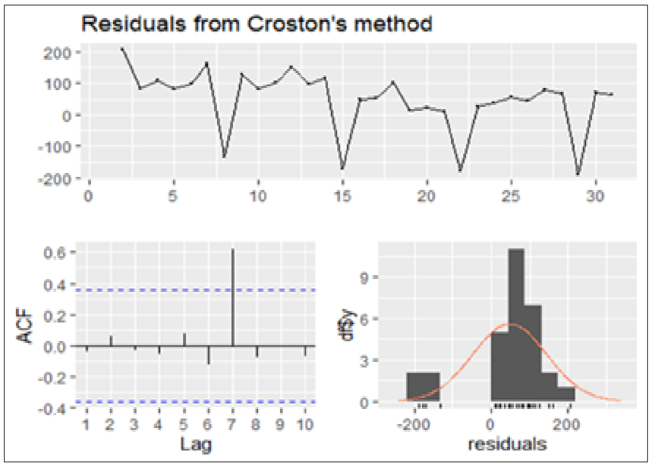

Fig 3: Muara Enim Store Residual Graph with Croston

From the picture above, we can find statistical values from the results of determining the forecast using the Croston method with a value of Q = 1.1246, DF = 6, and p-value = 0.9804. Next, the forecast results are shown in the following image

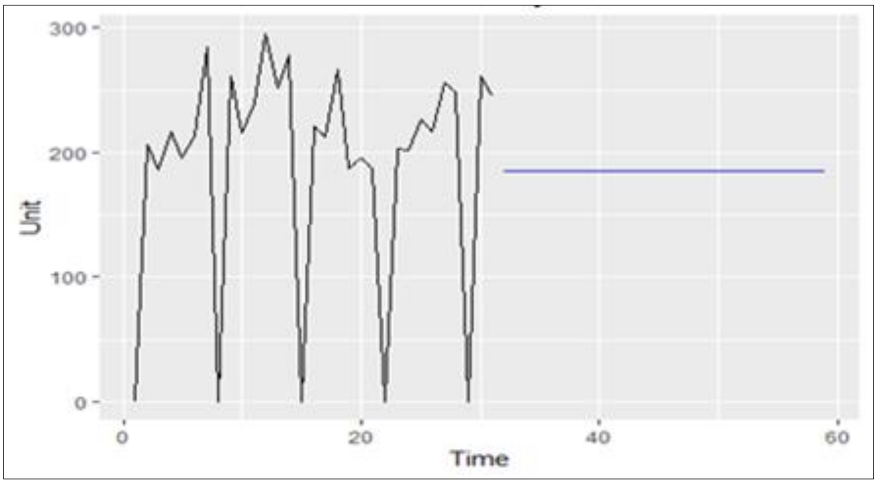

Fig 4: Forecast graph of Muara Enim Stores with Croston

The forecast results visualized in the graph above will then be used to calculate the amount that must be fulfilled at the Muara Enim Store. The next forecasting experiment, using the Seasonal ARIMA method, obtained a residual graph, as shown in the image below.

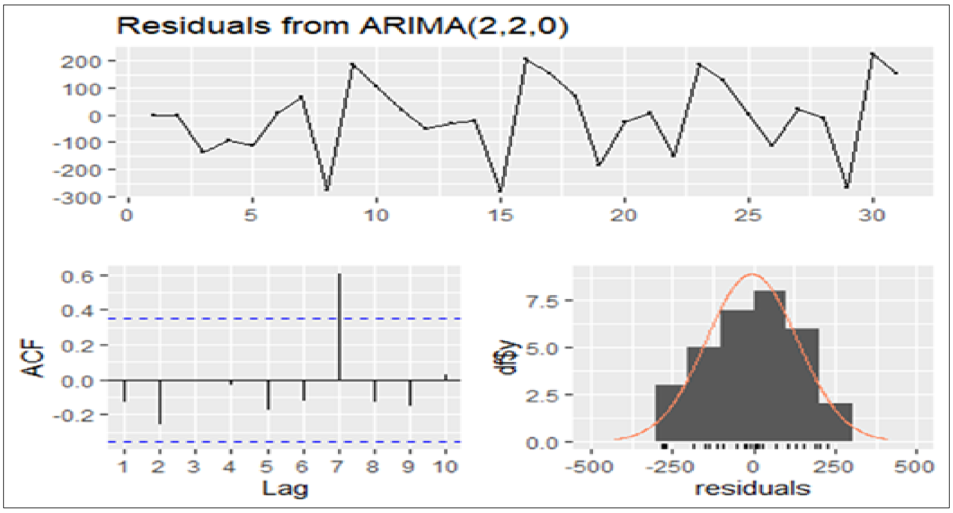

Fig 5: Muara Enim Store Residual Graph with ARIMA

The image above shows statistical values obtained from determining the forecast using the Croston meth, OD with a value of Q = 4.8247, DF = 4, and d p-value = 0.3058Thehe forecast results are shown in the following image.

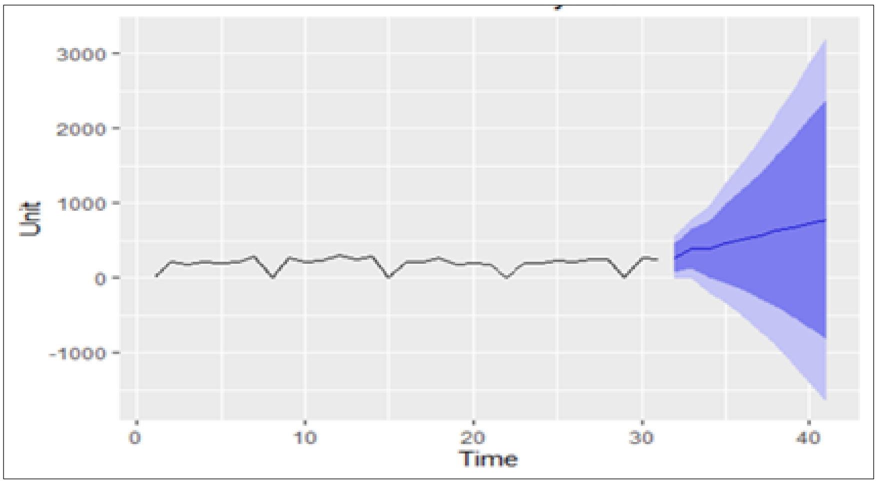

Fig 6: Muara Enim Store Forecast Graph Using ARIMA

Figure 5 and Figure 7 show two graphs of the forecast results. The forecast value using the Croston method shows a

constant value while using the ARIMA method, the forecast results tend to show an increase in the coming period.
Furthermore, after determining the forecast for the needs of 1 store in February 2023, the accuracy of the forecast results is shown based on 3 error values: ly mean error (M,E), root mean square error (RMS, and E), and mean absolute error (MAE) [29,30]. The error values for the forecast results for each Sto are shown in the table below.

Table 1: Error value of forecast results

Store Name	Croston Method			ARIMA Method		
	ME	RMSE	MAE	ME	RMSE	MAE
Muara Enim	47,68	106,23	92,41	-6,64	137,8	106,31
Pagar Alam	34,09	103,45	87,06	-18,86	120,3	99,03
Lubuk Linggau	49,88	112,9	97,18	-11,85	138,2	112,36
Banyuasin	41,98	103,46	90,01	-10,23	117,12	100,47
Lahat	11,36	93,55	72,63	-4,68	123,02	96,99
Bungo	29,38	83,21	68,32	-7,14	99,79	80,55
Batang Hari	41,93	86,35	70,47	0,14	108,63	86,26
Kerinci	-10,19	90,26	69,7	-16,14	94,25	68,19
Lebong	35,97	111,21	89,35	-7,48	141,6	114,69
Kepahiang	36,83	111,14	90,62	-10,16	145,71	121,17

Table 1 shows the error values from forecasting results using Croston and ARIMA methods. From the results of comparing the error values between the two methods used, the Croston method has a better error value than the ARIMA method. The Croston method forecast results are used to determine the demand for all Stores in the South Sumatra area. Furthermore, the forecast values for each store in the South Sumatra area are shown in the following table:

Table 2: Forecast Results for South Sumatra Stores Store Forecast Result

Store	Forecast Result
Muara Enim	5180
Pagar Alam	4676
Lubuk Linggau	5236
Banyuasin	4424
Lahat	3892
Bungo	3052
Batang Hari	2576
Kerinci	3220
Lebong	5572
Kepahiang	5432

Table 2 shows the forecasting results for all Stores in the South Sumatra area. This forecast value will be the supply requirement for 3 depots in the South Sumatra area.

3. 2 Transportations Model

After knowing the amount that must be supplied for each store based on the forecasting results using the Croston method, the next step is to determine the transportation process model using the transportation method. The purpose of determining this model is to determine the amount that must be supplied at each store and from which depot it will be supplied so that optimal costs are obtained. The transportation model applied by the previous company was determined using the northwest corner method or based on the area in each depot. The maximum capacity that each depot can supply is 20,000 units. Next, using the demand forecast that has been determined, the determination of the transportation model using the northwest corner method is as follows:

Table 3: Northwest Corner Method Transportation Model

Dest. / DC	Muara Enim	Pagar Alam	Lubuk Linggau	Banyuasin	Lahar	Bungo	Batang Hari	Kerinci	Lebong	Kepahiang	Total Supply
DC Palembang	456	713	786	126	564	1.297	813	1.733	1.113	957	20.000
	5.180	4.676	5.236	4.424	484						
DC Jambi	856	1.116	783	771	965	710	224	1.078	1.108	1.005	12.256
					3.408	3.052	2.576	3.220			
DC Bengkulu	657	428	300	1.221	635	1.078	937	1.098	300	234	11.004
									5.572	5.432	
Total Supply	5.180	4.676	5.236	4.424	3.892	3.052	2.576	3.220	5.572	5.432	43.260
Demand	5.180	4.676	5.236	4.424	3.892	3.052	2.576	3.220	5.572	5.432	

Based on the table above, using the northwest corner method, the costs incurred are obtained using the following calculations:
Total Cost with NWC: (456 x 5180) + (713 x 4676) + (786x5236) + (126 x 4424) + (564 x 484) + (965 x 3408) + (710 x 3052) + (224 x 2576) + (1078 x 3220) + (300 x 5572) + (234 x 5432) = Rp. 23.084.066
From the calculation results above, the transportation costs

required using the northwest corner method are IDR. 23,084,066.

The next stage is to optimize the transportation model using the linear programming method with the help of Lingo software using the following objective function:

Objective Function:

Min Z = $\sum_{i=1}^{m}\sum_{j=1}^{n} \boldsymbol{C}$I, jXi, j ……………….. eq. (1)

Based on the objective function above, this linear programming mathematical model aims to minimize total supply costs in product distribution activities from depots to Stores to reduce high costs due to less-than-optimal product distribution processes. From this objective function, there are several obstacles in minimizing distribution costs as follows:

Source capacity constraint function:

Si = $\sum_{i=1}^{m} \boldsymbol{X}$ij ……………….. eq. (2)

Requirement constraint function:

Di = $\sum_{j=1}^{n} \boldsymbol{X}$ij……………….. eq. (3)

Notations:

$\sum_{i=1}^{m} \boldsymbol{X}$ij= $\sum_{j=1}^{n}$ Atau Si = Di

Remarks:

Cij = Transportation costs per unit of goods from DC i to destination Store j

Xij = Number of goods distributed from DC i to destination Store j ≥ 0

Si = Total capacity of Deposit i

Dj = Number of Store requirements j

m = Number of DC

n = Number of Stores

The results using the linear programming transportation model method for Storing in the South Sumatra area are as follows:

Table 4: Transportation Model Using Linear Programming

Dest./DC	**Muara Enim**	**Pagar Alam**	**Lubuk Linggau**	**Banyuasin**	**Lahar**	**Bungo**	**Batang Hari**	**Kerinci**	**Lebong**	**Kepahiang**	**Total Supply**
DC Palembang	456	713	786	126	564	1.297	813	1.733	1.113	957	14.412
	5.180	916		4.424	3.892						
DC Jambi	856	1.116	783	771	965	710	224	1.078	1.108	1.005	8.848
						3.052	2.576	3.220			
DC Bengkulu	657	428	300	1.221	635	1.078	937	1.098	300	234	20.000
		3.760	5.236						5.572	5.432	
Total Supply	5.180	4.676	5.236	4.424	3.892	3.052	2.576	3.220	5.572	5.432	43.260
Demand	5.180	4.676	5.236	4.424	3.892	3.052	2.576	3.220	5.572	5.432	

Based on the table above, by using the linear programming method with Lingo software, the costs incurred are obtained using the following calculations:

Total Cost =

(456 x 5180) + (713 x 916) + (428 x 3760) + (300x5236) + (126 x 4424) + (564 x 3892) + (710 x 3052) + (224 x 2576) + (1078 x 3220) + (300 x 5572) + (234 x 5432) = Rp. 18.104.199

From the calculation results above, the transportation costs required using the linear programming method are IDR. 18,104,199.

After comparing the two methods used in determining the transportation model, it was found that using the linear programming method incurs smaller transportation costs than the northwest corner method, so the transportation model that will be tested for optimization is the model from the results of the linear programming method. Then, the requirements that must be supplied for each store will be grouped based on the depot supply center, and a distribution schedule will be determined for each day based on the daily forecast.

Table 5: Supply Store schedule

DC Palembang						
Cust Code	**Store Name**	**DC**	**Total Supply (Unit)**	**Demand (Days)**	**Supply Frequency**	**Volume Supply (Unit)**
A1	Store Muara Enim	DC Palembang	5180	185	10 Times	518
A2	Store Pagar Alam	DC Palembang	916	167	10 Times	92
A4	Store Banyuasin	DC Palembang	4424	158	10 Times	443
A5	Store Lahat	DC Palembang	3892	139	10 Times	390
DC Jambi						
Cust Code	**Store Name**	**DC**	**Total Supply**	**Demand (Days)**	**Supply Frequency**	**Volume Supply (Unit)**
A6	Store Bungo	DC Jambi	3052	109	10 Times	306
A7	Store Batang Hari	DC Jambi	2576	92	10 Times	258
A8	Store Kerinci	DC Jambi	3220	115	10 Times	322
DC Bengkulu						

Cust Code	Store Name	DC	Total Supply	Demand (Days)	Supply Frequency	Volume Supply (Unit)
A2	Store Pagar Alam	DC Bengkulu	3760	167	10 Times	376
A3	Store Lubuk Linggau	DC Bengkulu	5236	187	10 Times	524
A9	Store Lebong	DC Bengkulu	5572	199	10 Times	558
A10	Store Kepahiang	DC Bengkulu	5432	194	10 Times	544

After creating a distribution schedule for each depot, the next stage is to determine the delivery route that the car will take using the vehicle routing problem (VRP) method and the mixed integer linear programming method.

3.3 Vehicle routing problem (VRP)

After determining the transportation model, the results of determining the most optimal supply from each depot for each store were obtained. From the results of the transportation model, the supply distribution for DC Palembang was 4 Stores, DC Jambi was 3 Stores, and DC Bengkulu was 4 Stores. After all, stores have been classified based on their DC supply. The next stage is to optimize the route path by determining the route using the vehicle routing problem method to get the optimal route path. Route determination is carried out using the mixed integer linear programming (MILP) method with the help of Lingo software using the following objective function:

Objective Function:

$\text{Min } z = \sum_{i=1}^{n} \sum_{j=1}^{n} d_{ij} x_{ij}$ ………………. eq. (4)

Based on the objective function above, the aim of the mathematical model using mixed integer linear programming is to minimize the total distance traveled in product distribution activities from the DC to the store to reduce delays and high costs that occur due to poor route determination. From this objective function, there are several obstacles in determining the best route, including the following:

Constraint Function 1:

$\sum_{j=1}^{n} x_{ij} = 1 \quad \forall i = 2,\ldots, n$ ………………. eq. (5)

$\sum_{j=1}^{n} x_{ji} = 1 \quad \forall i = 2,\ldots, n$ ………………. eq. (6)

$\sum_{j=1}^{n} f_{ji} - \sum_{j=1}^{n} f_{ij} = D_i \quad \forall i = 2,\ldots, n$ ……. eq. (7)

$0 \leq f_{ij} \leq C x_{ij} \quad \forall i,j = 1,\ldots, n$

$x_{ij} \in \{0,1\} \quad \forall i,j = 1,\ldots, n$

Remarks:

n = Store Number (Store 1, Store 2,...., Store n).

did = Distance from point i to j

Di = Store Request i

C = Car carrying capacity

xij = 1 If the car goes from location i to location j (binary)

fij = Number of cars going from location i to location j

3.3.1 VRP DC palembang

At DC Palembang, the vehicle used to deliver goods is a Mitsubishi L300 with a transport capacity of 1500 units per trip. The initial stage in determining route optimization is to determine the volume to be supplied for each store and the distance matrix from each store. The total supply volume and distance matrix from each store are shown in the table below.

Table 6: Supply Volume of Palembang DC Area Per trip or one series of trips

	DC Palembang	Store Muara Enim	Store Pagar Alam	Store Banyuasin	Store Lahat
Demand	0	518	92	443	390

Table 7: Palembang DC Area Distance Matrix

	DC Palembang	Store Muara Enim	Store Pagar Alam	Store Banyuasin	Store Lahat
DC Palembang	0	181	283	50	224
Store Muara Enim	181	0	102	223	70
Store Pagar Alam	283	102	0	326	85
Store Banyuasin	50	223	326	0	300
Store Lahat	224	70	85	300	0

After obtaining the required parameters, the next step is to optimize the route determination using the mixed integer linear programming method with the help of Lingo 19.0 software. After optimization, the route obtained is as follows:

Table 8: Routes from the Latest Transportation Models in Palembang

No.	DC	Route	Distance (KM)	Qty (Unit)	Cost (Rp)	Trip (Times)	Total Cost (Rp)
1	DC Palembang	DC → Banyuasin → Muara Enim → Lahat → Pagar Alam → DC	711	1443	537.200	10	5.372.000
2	DC Jambi	DC → Batang Hari → Bungo → Kerinci → DC	986	886	744.978	10	7.449.778
3	DC Bengkulu	DC → Lubuk Linggau → Kepahiang → Pagar Alam → DC	485	1444	366.444	10	3.664.444
4	DC	DC → Lebong → DC	238	558	179.822	10	1.798.222

	Bengkulu						
Total			2.420	4.331	1.828.444	10	18.284.444

Berdasarkan dari tabel 8 biaya yang dibutuhkan berdasarkan dari hasil penentuan rute terbaik dengan menggunakan metode mix integer linear programing adalah sebesar Rp. 5.372.000.

3.3.2 VRP DC Jambi

At DC Jambi, the vehicle used to deliver goods is a Mitsubishi L300 car with a transport capacity of 1500 units per trip. The initial step in determining route optimization is to determine the amount of volume that will be supplied for each Sto and the distance matrix from each store. The total supply volume for each Sto and the distance matrix from each Sto are shown in the table below.

Table 9: Supply Volume of Jambi DC Area Per Trip

	DC Jambi	Store Bungo	Store Batang Hari	Store Kerinci
Demand	0	306	258	322

Table 10: Jambi DC Area Distance Matrix

	DC Jambi	Store Bungo	Store Batang Hari	Store Kerinci
DC Jambi	0	282	89	428
Store Bungo	282	0	202	267
Store Batang Hari	89	202	0	367
Store Kerinci	428	267	367	0

After obtaining the required parameters, the next step is to optimize the route determination using the mixed integer linear programming method with the help of Lingo 19.0 software. After optimization, the route obtained is as follows:

Table 11: Rute Dari Model Trasnportasi Terbaru DC Jambi

No.	Routing	Distance (Km)	Qty (Unit)	Cost (Rp)	Trip (Times)	Total Cost (Rp)
1	Depo → Batang Hari → Bungo → Kerinci → Depo	986	886	723.067	10	7,449,778

Based on Table 10, IDR is the cost required based on the results of determining the best route using the mixed integer linear programming method. 7,449,778.

3. 3.3 VRP DC bengkulu

At DC Bengkulu, the vehicle used to deliver goods is a Mitsubishi L300 with a transport capacity of 1500 units per trip. The initial step in determining route optimization is to determine the amount of volume that will be supplied for each Sto and the distance matrix from each store. The total supply volume for each Sto and the distance matrix from each Sto are shown in the table below.

Table 12: Supply Volume of Bengkulu DC Area per Trip

	DC Bengkulu	Store Pagar Alam	Store Lubuk Linggau	Store Lebong	Store Kepahiang
Demand	0	376	524	558	544

Table 13: Bengkulu DC Area Distance Matrix

	DC Bengkulu	Store Pagar Alam	Store Lubuk Linggau	Store Lebong	Store Kepahiang
DC Bengkulu	0	170	119	119	93
Store Pagar Alam	170	0	170	213	108
Store Lubuk Linggau	119	170	0	129	88
Store Lebong	119	213	129	0	128
Store Kepahiang	93	108	88	128	0

After obtaining the required parameters, the next step is to optimize the route determination using the mixed integer linear programming method with the help of Lingo 19.0 software. After optimization, the route obtained is as follows:

Table 14: Routes of the Latest Transportation Model in Bengkulu

Rute	Jalur Rute	Jarak (Km)	Qty (Unit)	Cost (Rp)	Trip (Times)	Total Cost (Rp)
1	Depo → Lubuk Linggau → Kepahiang → Pagar Alam → Depo	485	1444	366.444	10	3,664,440
2	Depo → Lebong → Depo	238	558	179.822	10	1.798.220
Total						5.452.660

Based on Table 13, IDR is the cost required based on the results of determining the best route using the mixed integer linear programming method. 5,452,660.

5. Discussion

After carrying out an analysis using the mixed integer linear programming method to determine transportation routes from transportation carried out using the linear programming method, then comparing it with the route determination carried out previously, the route determination results are obtained, which are shown in the following table:

Table 15: Routes from the previous distribution model

No.	DC	Route	Distance (KM)	Qty (KM)	Cost (Rp)	Trip (Times)	Total Cost (Rp)
1	DC Palembang	DC Depo — Lubuklinggau > Pagar Alam — Lahat — Depo	791	1.381	597.644	10	5.976.444
2	DC Palembang	DC Depo Banyuasm—> Muara Enim > Depo	454	961	343.022	10	3.430.222
3	DC Jambi	DC Jambi > Lahat—Kerinci > Bungo — Batang Hari > Depo	1.465	1.227	1.106.889	10	11.068.889
4	DC Bengkulu	DC Depo— Lebong— Kepahiang > Bengkulu — Depo	340	1.102	256.889	10	2.568.889
Total			**3.050**	**4.671**	**2.304.444**	**40**	**23.044.444**

The route from Table 14 is illustrated on the map to show the movement of shipments from one point to another.

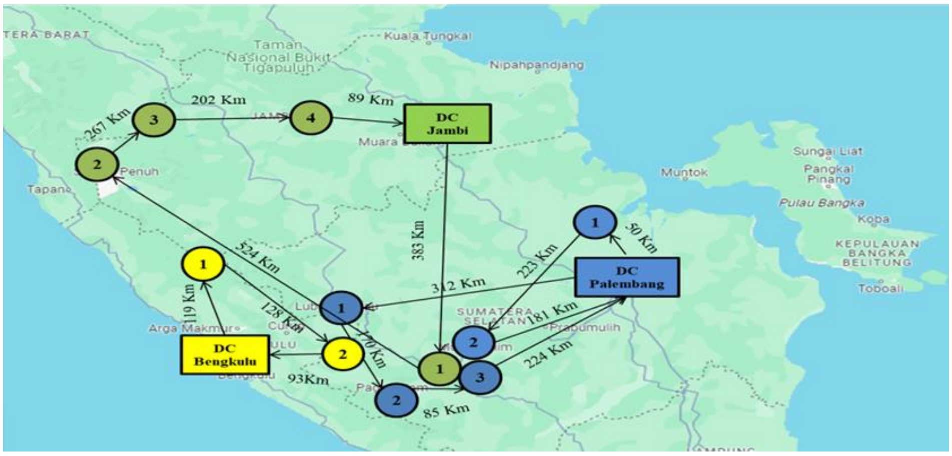

Fig 8: Route Graph before Repair

Figure 7 shows that the delivery point is inefficient in product distribution and routes, especially the Jambi DC route. The results of the analysis, as done above, can be seen in Table 15 below.

Tabel 16: MDVRP Dari Model Linear Programing As proposed Route Model

	DC	Route	Distance (KM)	Qty (Unit)	Cost (Rp)	Trip (Times)	Total Cost (Rp)
1	DC Palembang	DC → Banyuasin → Muara Enim → Lahat → Pagar Alam → DC	711	1443	537.200	10	5.372.000
2	DC Jambi	DC → Batang Hari → Bungo → Kerinci → DC	986	886	744.978	10	7.449.778
3	DC Bengkulu	DC → Lubuk Linggau → Kepahiang → Pagar Alam → DC	485	1444	366.444	10	3.664.444
4	DC Bengkulu	DC → Lebong → DC	238	558	179.822	10	1.798.222
Total			2420	4331	1.828.444	10	18.284.444

Table 15 shows that after the route changes based on the previous analysis, the total cost was reduced from Rp. 23,044,444 to Rp. 18,284,444. The efficiency in the form of a map image can be seen in Figure 8 below.

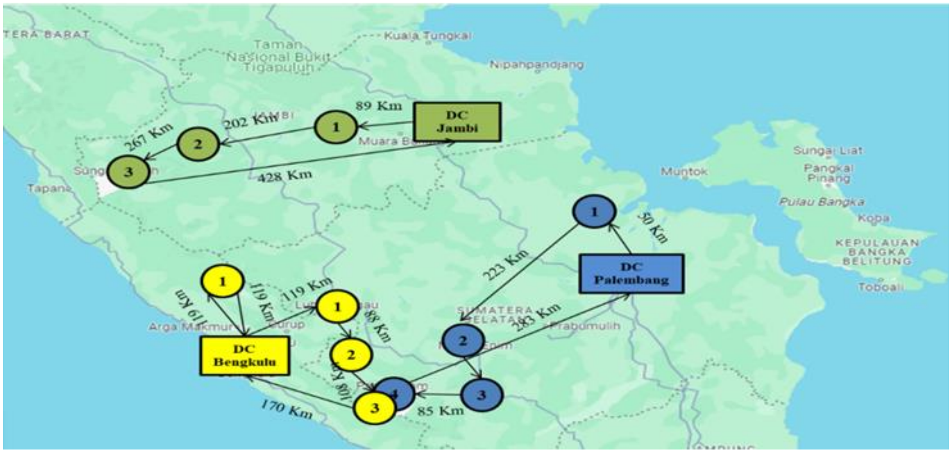

Fig 9: Route Graph after Repair as Proposed Model

After comparing the transportation route model determined using the mixed integer linear programming method and the transportation model using the northwest corner and linear programming, it was concluded that using the transportation model from the results of linear programming iterations had more optimal costs compared to the transportation model previously implemented by the company. Namely, the northwest corner method with a cost difference of Rp is used. 4,760,000 or 21%. So, this research can reduce the transportation costs companies must pay each month by 21%.

Conclusion

From comparing the two methods used in determining the transportation model, the linear programming method incurs smaller transportation costs than the northwest corner method. Hence, the transportation model that will be tested for optimization is the model from the results of the linear programming method. Based on the transportation model with linear programming, route determination using the mixed integer linear programming method for the South Sumatra area can minimize transportation costs by Rp. 4,760,000 or 21%. This research can be used as a reference for companies as recommendations for improvements in the process of transportation activities in other areas so that they can minimize their logistics operational costs as optimally as possible. Apart from that, this research can be used as a reference for similar research using the mixed integer linear programming method so that it can solve problems related to transportation.

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