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Strategic Optimization in Distribution Centers: Leveraging Relocation, P-Median, and GIS-Based Routing for Enhanced Efficiency

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***Abstract*—In the realm of B2C (Business-to-Customer) company marketing, it is imperative to focus on sales and customer satisfaction. To uphold customer contentment, B2C enterprises must strategically position their delivery facilities to optimize efficiency and minimize both time and operational expenditures. PT ABC, a B2C entity specializing in the distribution of packaged goods, currently faces challenges in handling a substantial volume of requests, some of which are situated far from their distribution centers. This predicament leads to elevated fulfillment costs and an inefficient operational process. Consequently, the relocation of distribution center facilities becomes a necessity. The relocation process will be executed employing the P-Median method, facilitated by LINGO software. The P-Median analysis yielded three potential new locations: Cikupa, Jombang Wetan, and Bencongan Indah. Subsequently, further assessment was conducted through the resolution of the MTCVRP (Multitrip Capacitated Vehicle Routing Problem) with the aid of ArcGIS software. As a result, Jombang Wetan emerged as the optimal candidate, exhibiting a remarkable reduction of 165.7 kilometers or a 31.33% decrease in average mileage. This choice promises a more efficient and effective product distribution operation.**

***Keywords*: Business to Customer, Distribution Center, Multitrip Capacitated Vehicle Routing Problem, P-Median**

I. INTRODUCTION

B2C (Business to Customer) enterprises are those engaged in direct transactions with individual consumers. Marketing within this sector primarily hinges on emotional factors, underscoring that B2C entities must not solely prioritize sales but must also emphasize customer satisfaction(Rėklaitis&Pilelienė, 2019). It is incumbent upon B2C service providers to promptly address customer inquiries and requirements within their stipulated timeframes. To optimize their service offerings and uphold customer contentment, B2C corporations must meticulously manage their service durations, particularly product delivery times, ensuring they remain expeditious. Hence, B2C companies should diligently consider the placement of their distribution facilities to align with demand patterns. They must also implement efficient routing strategies to minimize both time and operational expenditures. Such challenges typically manifest for distribution centers or warehouses that cater to multiple retail locations.

Presently, the rapid expansion of B2C companies in Indonesia presents a highly promising opportunity. In the wake of the COVID-19 pandemic, B2C e-commerce is anticipated to experience a consistent growth rate of 15.56% from 2022 through 2026(BusinessWire, 2022). Online shopping has become an ingrained lifestyle choice, characterized by the preference for minimal physical interaction and the convenience of acquiring goods from the comfort of one's home. Within this landscape, each B2C enterprise must strive to establish a distinctive and appealing value proposition for its customers. One such crucial aspect is the provision of safe, expedient, and cost-effective logistics services. This strategic imperative aligns seamlessly with the issues observed in the subject of examination, namely a B2C company functioning as a distribution center for packaged products. The organization currently grapples with a multitude of customer requests dispersed across various locations, some of which are considerably distant from the distribution center's geographic hub.

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This predicament results in escalated distribution expenses and a suboptimal distribution workflow. Furthermore, the company operates a single transportation fleet with a maximum capacity of 2 tons and refrains from outsourcing delivery services. The influx of orders through the Manuva Retail application is characterized by high volume and diversity, rendering predictability challenging. In light of these challenges, the most suitable course of action to enhance the efficiency of the product distribution process is the relocation of the distribution center. Consequently, the pivotal step involves the systematic allocation of the new distribution center's location.

Fig 1. Existing Demand Points

Imperative to conduct a comprehensive literature review. This review serves several critical purposes: firstly, it facilitates the identification of the variables that warrant investigation; secondly, it enables the differentiation of prior research accomplishments; thirdly, it aids in pinpointing areas necessitating innovation and the infusion of fresh perspectives; fourthly, it fosters a profound comprehension of each theory slated for utilization within the research process; and lastly, it establishes the significance and interconnections between variables. These aspects collectively contribute to the realization of the research objectives, which pertain to devising a novel warehouse location solution for the Serang branch of PT ABC and optimizing routing to enhance the efficiency of distribution operations.

Regarding the resolution of the allocation location quandary, there exists a variety of methodologies at one's disposal, among which the P-Median method stands out. The P-Median approach finds utility not only in determining warehouse relocations(Zapata et al., 2020) but also in the establishment of distribution centers(Asmara &Ichtiarto, 2021), (Fadhil (Universitas Pertamina) et al., 2020). The implementation of P-Median can be accomplished via the utilization of software applications such as LINDO or LINGO(Zapata et al., 2020),(Pribadi&Permatasari, 2021). The initial step in ascertaining the novel site entails gauging the distances between potential facilities employing the Haversine Method, based on known coordinate data(Fadhil (Universitas Pertamina) et al., 2020). Subsequent research findings corroborate that the proposed locations determined by the P-Median method have the potential to curtail delivery distances(Zapata et al., 2020), consequently leading to a reduction in transportation costs(Fadhil (Universitas Pertamina) et al., 2020). It is worth noting that prior investigations into the application of P-Median typically present scenarios based solely on aggregated demand, yielding a solitary set of location proposals. Furthermore, these previous studies commonly lack subsequent analyses delineating distribution routes emanating from the selected candidate locations, a deficiency that this study endeavors to rectify.

Moreover, to enhance the precision of the relocation assessment, an in-depth analysis is conducted employing the Multitrip Capacitated

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Vehicle Routing Problem (MTCVRP) model. This model amalgamates the principles of the Multitrip Vehicle Routing Problem, as exemplified in studies by(Widyastiti&Awaludin, 2021), (Mingozzi et al., 2013),(Cattaruzza et al., 2018), and(Ramadhani et al., 2021). The Multitrip Vehicle Routing Problem encompasses scenarios in which the cargo volume or quantity surpasses the vehicle's carrying capacity, necessitating multiple vehicles to visit specific demand points.

Subsequently, this model is integrated with the Capacitated Vehicle Routing Problem (CVRP) model, as demonstrated in the research conducted by(Lukmandono et al., 2019),(A. Purnomo., 2017), (Kristina et al., 2020), and(Linfati& Escobar, 2018), which takes into account the vehicle's capacity constraints. The primary objective of employing the Multitrip Capacitated Vehicle Routing Problem (MTCVRP) is to minimize the distance traversed during the distribution of goods. The forthcoming research endeavors to deduce the optimal relocation site from the pool of three candidates, drawing comparisons based on the average mileage at the current location. It's noteworthy that previous research has not ventured into the fusion of the Multitrip Capacitated Vehicle Routing Problem and Capacitated Vehicle Routing Problem models, nor has it made use of a Geographic Information System (GIS). This study aims to bridge this gap by amalgamating these two models and employing a Geographic Information System (GIS) for its application.

When juxtaposed with preceding literature studies, the scientific innovation of this research centers on the introduction of case studies and the application of advanced analyses. Historically, studies focused on optimizing distribution in packaging distributor companies in Indonesia have been scarce and not extensively pursued. Contrastingly, packaging holds considerable significance in Indonesia, particularly for various industries, including the burgeoning food sector(A. N. Sari, 2022). Ensuring the timely and adequate availability of packaging materials is of paramount importance for logistics companies like this packaging distributor. Furthermore, in contrast to prior literature, no prior research has undertaken advanced analyses of the P-Median location problem with a simultaneous exploration of route optimization using the MTCVRP framework. Additionally, the utilization of the MTCVRP model remains relatively uncommon in case studies. Hence, the scientific novelty of this research entails the fusion of mathematical models encompassing multi-trip VRP and CVRP, tailored to the specifics of the case study. This distinctiveness underscores the research's novel approach, which involves the integration of two disparate methods as part of an advanced analysis, rather than merely employing them for comparative purposes.

I. METHODOLOGY

The problem-solving methodologies employed here are bifurcated into two categories: data collection methods and analytical methods. Data collection was carried out through interviews conducted with the Manuva Retail warehouse personnel. This interview yielded a comprehensive understanding of the problem at hand and provided essential data. The data encompassed various elements, such as the company's demand and demand allocation specifics, preferred candidate locations, and specifications concerning the company's transportation modes. The location data, upon acquisition, underwent initial processing to calculate the distance between various points. The Haversine method was the chosen approach for distance computation. The Haversine method employs an equation to ascertain the great circle distance (radius) between two points on the Earth's surface, taking into account their longitude and latitude coordinates. The requisite points for this study were sourced via the Google Maps search tool, which provided longitude and latitude coordinates(Fadhil (Universitas Pertamina) et al., 2020).

$$x = (Lt_2 - Lt_1) \times \cos\left(\frac{L_2 + L_1}{2}\right) \quad (1)$$

$$y = Lt_2 - Lt_1 \quad (2)$$

$$d = \sqrt{(x \times x) + (y \times y)} \times R \quad (3)$$

Notes:
x = Longitude
y = Latitude
d = Distance
R = Radius of Earth = 6.371 km
1 degree = 0.0174532925 radian

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Furthermore, the data obtained will be processed with the P-Median method to solve the warehouse transfer locations. The P-Median mathematical model used is as follows(Fadhil (Universitas Pertamina) et al., 2020).

P-Median Method

Inputs:

h_i = Demandat point i ∈ I

P = The number of ditribution centers to buld

$d_{ij} = D$

$\in Ia$ $\in J$

Decision Variabels:

$$Y_{ij} = \begin{cases} 1, & \text{Valued 1 if the demand at point } i \in I \text{ is met by distribution center } j \in J \\ 0, & \text{Valued 0 otherwise} \end{cases}$$

$$X_j = \begin{cases} 1, & \text{Valued 1 if the candidate facility is built at node } j \in J \\ 0, & \text{Valued 0 otherwise} \end{cases}$$

Objective Function:

$$M \quad \sum_{i \in I} \sum_{j \in J} h_i d_{ij} Y_{ij} \quad (4)$$

Constraints:

Subject to

$$\sum_{j \in J} Y_{ij} = 1 \qquad \forall i \in I \qquad (5)$$

$$\sum_{j \in J} X_j = P \qquad (6)$$

$$Y_{ij} - X_j \leq 0 \qquad \forall i \in I;\ \forall j \in J \qquad (7)$$

$$X_{ij} \in \{1,0\} \qquad \forall j \in J \qquad (8)$$

$$Y_{ij} \in \{1,0\} \qquad \forall i \in I;\ \forall j \in J \qquad (9)$$

The objective function, denoted as(Asmara &Ichtiarto, 2021), stipulates the minimization of the product of the demand point and its distance to the nearest facility. Constraint(Fadhil (Universitas Pertamina) et al., 2020) enforces the requirement that each point i within set I is exclusively serviced by one facility j within set J. Constraint(Pribadi&Permatasari, 2021) mandates the establishment of a fixed number of P facilities. Constraint(Widyastiti&Awaludin, 2021)establishes a link between the facility location decision Xj and the allocation variable Yij, ensuring that the demand at point i within set I can solely be allocated to facility j within set J. Constraints(Mingozzi et al., 2013)and(Cattaruzza et al., 2018)are responsible for dictating that the decision variables X and Y assume binary values (0 or 1), while Y remains non-negative.

Subsequently, after selecting the candidate locations, the subsequent analysis revolves around determining the optimal routing through the application of the Multitrip Capacitated Vehicle Routing Problem (MTCVRP) methodology. This choice is motivated by its consideration of transportation capacity allocation for each customer to be served. The mathematical model for the Multitrip Capacitated Vehicle Routing Problem (MTCVRP), as sourced from(Kristina et al., 2020) and(Ramadhani et al., 2021), is as follows.

Multitrip Capacitated Vehicle Routing Problem (MTCVRP) Method

Objective Function

$$\text{Min } \sum_k \sum_i \sum_j d_{ij} x_{ijkt} \qquad (10)$$

With

$$x_{ijkt} = \begin{cases} 1, & \text{if there is the visit from point i to to point j by vehicle k on the tth } t_i \\ 0, & \text{if not} \end{cases}$$

Constraints

$$\sum_j x_{ijkt} \leq 1 \qquad \forall t, k, i = 1 \qquad (11)$$

$$\sum_i \sum_k \sum_t x_{ijkt} \geq 1 \qquad \forall j \qquad (12)$$

$$\sum_i \sum_j U_j x_{ijkt} \leq Q_k \qquad \forall k \qquad (13)$$

$$\sum_i x_{ijkt} - \sum_j x_{ijkt} \leq 1 \qquad \forall k, t \qquad (14)$$

$$\sum_i x_{ijkt} - \sum_j x_{ijkt} = 0 \qquad \forall k, t \qquad (15)$$

$$x_{ijkt} + x_{jikt} \leq 1 \qquad \forall i, j, k, t \qquad (16)$$

$$x_{ijkt} \in \{0,1\} \qquad \forall i, j, k \qquad (17)$$

The objective function, as represented by equation(Ramadhani et al., 2021), articulates the objective of minimizing the transportation distance. Constraint(Lukmandono et al., 2019)guarantees the ability for vehicles to be utilized more than once, allowing for multiple trips. Constraint(A. Purnomo., 2017)establishes the flexibility for each demand point to be visited repeatedly by the vehicle. The constraint(Kristina et al., 2020)specifies that each vehicle's transportation capacity must not be exceeded during the routing process. Constraint(Linfati&

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Escobar, 2018)underscores the necessity for the routing process to maintain continuity, signifying that vehicles departing from the depot must return to it. Additionally, Constraint(A. N. Sari, 2022)mandates that once a vehicle arrives at one customer location, it must proceed to another destination.

II. RESULTANDDISCUSSION

In this investigation, we employed three distinct sets of sample data, specifically, data pertaining to the day characterized by the highest demand observed on December 6, 2022, data representative of the average demand witnessed on December 9, 2022, and data indicative of the lowest demand experienced on December 7. These three distinct scenarios, each comprising three individual data samples, were deliberately selected from within the same calendar week, a measure implemented to account for the inherent uncertainty associated with consumer demand. Furthermore, this sampling strategy was implemented to prevent excessive aggregation of demand data, thereby mitigating the potential for generating assumptions that deviate significantly from the true situational context. The data acquired for these scenarios are presented in Tables 1, 2, and 3.

Table 1. The Most Demand Point Data

Date	Location	Demand(Kg)
6-Des-2022	Cibeber	275
	Cikupa	5500
	Citangkil	660
	Ciwaduk	1155
	Ciwedus	275
	Gunungsugih	275
	Harjatani	330
	Kebonsari	165
	Kramatwatu	55
	Lopang	330
	Randakari	110
	Tamansari	660
	Warnasari	385

Table 2. Average Demand Point Data

Date	Location	Demand(Kg)
9-Des-2022	Gedong Dalem	275
	JombangWetan	3190
	Kebondalem	220
	Kramatwatu	165
	Mekarsari	1485
	Panyaungan Jaya	55
	Sajira	1155
	Tamansari	1485

Table 3. The Least Demand Point Data

Date	Location	Demand(Kg)
7-Des-2022	Babakanlor	1375
	Bencongan Indah	10560
	Dalung	165
	Labuan	2530
	Serang	55
	Teluk	55

After the initial data collection, a series of computational procedures are applied to ascertain the spatial separation among prospective facility sites. In every scenario examined, each geographical point is regarded as a potential facility relocation candidate. The calculation of

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distances is executed employing the Haversein Method, requiring the conversion of longitude and latitude coordinates into radian units. The outcomes of these distance computations for each dataset are presented in Tables 4, 5, and 6.

Table 4. Distance Matrix between Facilities on Most Demand Point Data

Facility Candidate	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0	15	41	19	17	17	27	14	10	8	3	24	28	22
2	15	0	56	5	3	4	14	2	6	7	13	11	14	8
3	41	56	0	60	58	58	67	55	61	49	43	65	67	63
4	19	5	60	0	2	3	11	6	2	11	17	8	11	3
5	17	3	58	2	0	2	11	4	3	10	16	9	12	5
6	17	4	58	3	2	0	10	4	4	10	16	8	13	6
7	27	14	67	11	11	10	0	14	9	19	24	4	15	9
8	14	2	55	6	4	4	14	0	7	6	12	11	15	9
9	20	6	61	2	3	4	9	7	0	12	19	6	10	2
10	8	7	49	11	10	10	19	6	12	0	7	17	20	14
11	3	13	43	17	16	16	24	12	19	7	0	22	27	20
12	24	11	65	8	9	8	4	11	6	17	22	0	13	6
13	28	14	67	11	12	13	15	15	10	20	27	13	0	9
14	22	8	63	3	5	6	9	9	2	14	20	6	9	0

Table 5. Distance Matrix between Facilities on Average Demand Point Data

Facility Candidate	1	2	3	4	5	6	7	8	9
1	0	18	17	19	8	51	22	48	28
2	18	0	3	2	10	66	27	64	11
3	17	3	0	2	9	66	25	63	12
4	19	2	2	0	11	67	26	65	10
5	8	10	9	11	0	58	21	55	20
6	51	66	66	67	58	0	67	49	74
7	22	27	25	26	21	67	0	46	35
8	48	64	63	65	55	49	46	0	74
9	28	11	12	10	20	74	35	74	0

Table 6. Distance Matrix between Facilities on the Least Demand Point Data

Facility Candidate	1	2	3	4	5	6	7
1	0	47	49	6	51	21	49
2	47	0	83	42	5	35	6
3	49	83	0	51	88	69	88
4	6	42	51	0	46	19	44
5	51	5	88	46	0	37	3
6	21	35	69	19	37	0	35
7	49	6	88	44	3	35	0

Following the calculation of distances between potential facility sites, the subsequent phase entails data processing through the utilization of LINGO software to derive an optimal location for a new distribution center. The methodology applied for determining this new distribution center's location is the P-Median approach.

Below is the LINGO formula corresponding to the scenario characterized by the highest

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demand points:

```
!P-MEDIAN MODEL;
SETS:
SET_I/1..14/:H;
SET_J/1..14/:X;
LINK_IJ(SET_I,SET_J):D,Y;
ENDSETS
DATA:
D=
```

0	15	41	19	17	17	27	14	10	8	3	24	28	22
15	0	56	5	3	4	14	2	6	7	13	11	14	8
41	56	0	60	58	58	67	55	61	49	43	65	67	63
19	5	60	0	2	3	11	6	2	11	17	8	11	3
17	3	58	2	0	2	11	4	3	10	16	9	12	5
17	4	58	3	2	0	10	4	4	10	16	8	13	6
27	14	67	11	11	10	0	14	9	19	24	4	15	9
14	2	55	6	4	4	14	0	7	6	12	11	15	9
20	6	61	2	3	4	9	7	0	12	19	6	10	2
8	7	49	11	10	10	19	6	12	0	7	17	20	14
3	13	43	17	16	16	24	12	19	7	0	22	27	20
24	11	65	8	9	8	4	11	6	17	22	0	13	6
28	14	67	11	12	13	15	15	10	20	27	13	0	9
22	8	63	3	5	6	9	9	2	14	20	6	9	0

;

```
H= 0 5 100 12 21 5 5 6 3 1 6 2 12 7;
P=1;
ENDDATA
MIN =
@SUM(SET_I(I):@SUM(SET_J(J):H(I)*D(I
,J)*Y(I,J)));

@FOR(SET_I(I):@SUM(SET_J(J):Y(I,J))=
1);
@SUM(SET_J(J):X(J))=P;
@FOR(SET_I(I):@FOR(SET_J(J):Y(I,J)-
X(J)<=0));
@FOR(SET_J(J):@BIN(X(J)));
@FOR(SET_I(I):@FOR(SET_J(J):@BIN(
Y(I,J))));
```

In light of the outcomes generated from the data processing associated with the day featuring the greatest demand points, the optimal site for the distribution center is determined to be X3 (Candidate Location Three), as indicated in Table 7 below. This selection aligns with the data presented, designating Cikupa as the third location candidate.

Table 7. Facility Candidates at the Most Demand Points

Candidate	Location
K1	Dapur Sunda
K2	Cibeber
K3	Cikupa
K4	Citangkil
K5	Ciwaduk
K6	Ciwedus
K7	Gunungsugih
K8	Harjatani
K9	Kebonsari
K10	Kramatwatu
K11	Lopang
K12	Randakari
K13	Tamansari
K14	Warnasari

Subsequently, an analogous set of procedures is executed using data reflecting average demand points. Presented below are the mathematical formulations employed in LINGO for datasets characterized by average demand points.

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```
!P-MEDIAN MODEL;
SETS:
SET_I/1..9/:H;
SET_J/1..9/:X;
LINK_IJ(SET_I,SET_J):D,Y;
ENDSETS

DATA:
D=
```

0	18	17	19	8	51	22	48	28
18	0	3	2	10	66	27	64	11
17	3	0	2	9	66	25	63	12
19	2	2	0	11	67	26	65	10
8	10	9	11	0	58	21	55	20
51	66	66	67	58	0	67	49	74
22	27	25	26	21	67	0	46	35
48	64	63	65	55	49	46	0	74
28	11	12	10	20	74	35	74	0

```
;
H= 0 5 58 4 3 27 1 21 27;
P=1;
ENDDATA
MIN =
@SUM(SET_I(I):@SUM(SET_J(J):H(I)*D(I
,J)*Y(I,J)));

@FOR(SET_I(I):@SUM(SET_J(J):Y(I,J))=
1);
@SUM(SET_J(J):X(J))=P;
@FOR(SET_I(I):@FOR(SET_J(J):Y(I,J)-
X(J)<=0));
@FOR(SET_J(J):@BIN(X(J)));
@FOR(SET_I(I):@FOR(SET_J(J):@BIN(Y(I
,J))));
```

Following the data processing conducted on the day marked by the highest demand points, the determination of the new distribution center's location identifies X3 (Candidate Location Three) as the optimal choice, corresponding to the third location candidate, JombangWetan, as substantiated in Table 8 below.

Table 8. Facility Candidate at Demand Point Average

Candidate	Location
K1	Dapur Sunda
K2	Gedong Dalem
K3	JombangWetan
K4	Kebondalem
K5	Kramatwatu
K6	Mekarsari
K7	Panyaungan Jaya
K8	Sajira
K9	Tamansari

Ultimately, the process of site selection is executed using the dataset featuring the lowest demand points. Presented below is the LINGO formula relevant to datasets characterized by the minimal demand point.

```
!P-MEDIAN MODEL;
SETS:
SET_I/1..7/:H;
SET_J/1..7/:X;
LINK_IJ(SET_I,SET_J):D,Y;
ENDSETS

DATA:
D=
```

0	47	49	6	51	21	49
47	0	83	42	5	35	6
49	83	0	51	88	69	88
6	42	51	0	46	19	44
51	5	88	46	0	37	3
21	35	69	19	37	0	35
49	6	88	44	3	35	0

```
;
H= 0 25 192 3 46 1 1;

P=1;
ENDDATA

MIN =
@SUM(SET_I(I):@SUM(SET_J(J):H(I)*D(I
,J)*Y(I,J)));

@FOR(SET_I(I):@SUM(SET_J(J):Y(I,J))=
1);
@SUM(SET_J(J):X(J))=P;
@FOR(SET_I(I):@FOR(SET_J(J):Y(I,J)-
X(J)<=0));
@FOR(SET_J(J):@BIN(X(J)));
@FOR(SET_I(I):@FOR(SET_J(J):@BIN(Y(I
,J))));
```

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Following the outcomes of the data processing conducted on the day with the highest demand points, the optimal site for the distribution center is determined to be X3 (Candidate Location Three), in alignment with the dataset displayed below, with the third location candidate identified as Bencongan Indah, as illustrated in Table 9 below.

Table 9. Facility Candidates at the Least Demand Point

Candidate	Location
K1	Dapur Sunda
K2	Babakanlor
K3	Bencongan Indah
K4	Dalung
K5	Labuan
K6	Serang
K7	Teluk

Following the acquisition of three prospective distribution center locations, specifically Cikupa, JombangWetan, and Bencongan Indah, the subsequent phase entails routing optimization employing ArcGIS software. The company possesses a single fleet with a maximum cargo capacity of 2,000 kg. Consequently, the routing problem addressed in this investigation is the Multitrip Capacitated Vehicle Routing Problem (MTCVRP), as it incorporates constraints related to vehicle load capacity. Utilizing ArcGIS, data processing was conducted for each of the three candidate facility locations. The routing outcomes, should the distribution center remain in Serang, are depicted in Figure 2.

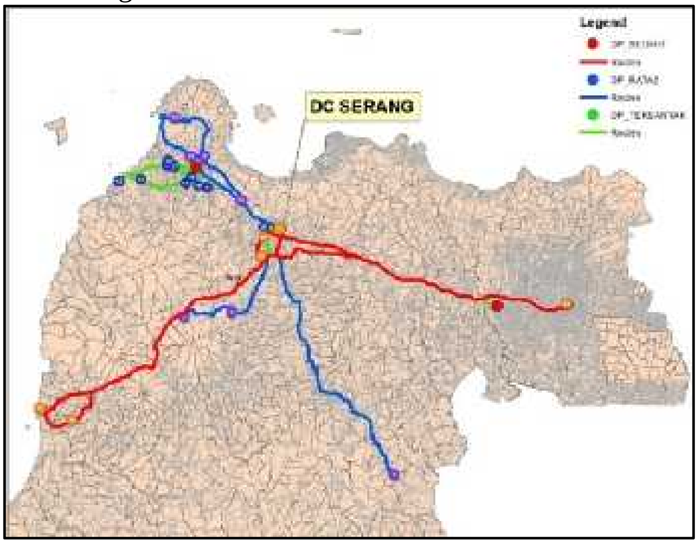

Fig 2. Existing Distribution Routes

The distribution routing analysis is performed for three distinct scenarios derived from the prior data samples, specifically, routing for the day characterized by the highest, average, and lowest demand points. The routing outcomes, along with the corresponding cargo capacity achievable when utilizing the distribution center located in Serang, are presented in Table 10. Notably, the average distance covered across these three scenarios from the current distribution center location amounts to 528.95 kilometers.

Table 10. Routing Details with Distribution Center in Serang (Baseline)

Routes with the Most Demand Points			
No.	**Routes**	**Quantity (kg)**	**Distance (km)**
1	DC – Cikupa - DC	1500	80,68
2	DC – Cikupa - DC	2000	80,68
3	DC – Cikupa - DC	2000	80,68

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4	DC - Kramatwatu - Harjatani - Cibeber - Ciwedus - Randakari - Gunungsugih - Warnasari - DC	1705	68,82
5	DC - Citangkil - Kebonsari - Ciwaduk - DC	1980	48,36
6	DC - Tamansari - Lopang - DC	990	41,00
	Total	10175	400,23
	Routes with Average Demand Points		
1	DC - Panyaungan Jaya - Tamansari - DC	1540	55,91
2	DC - Sajira - DC	1155	108,43
3	DC - JombangWetan - DC	2000	37,46
4	DC - Gedong Dalem - Mekarsari - Kebondalem - DC	1980	65,93
5	DC - JombangWetan - Kramatwatu - DC	1355	37,80
	Total	8030	305,52
	Route with Fewest Demand Points		
1	DC - Labuan - DC	2000	119,87
2	DC - Bencongan Indah - DC	2000	103,61
3	DC - Bencongan Indah - DC	2000	103,61
4	DC - Bencongan Indah - DC	2000	103,61
5	DC - Bencongan Indah - DC	2000	103,61
6	DC - Bencongan Indah - DC	2000	103,61
7	DC - Labuan - Teluk - Babakanlor - DC	1960	125,06
8	DC - Bencongan Indah - Dalung - Serang - DC	780	118,11
	Total	14740	881,10

Furthermore, distribution routing is carried out by setting up a distribution center in Cikupa. The routing results with the Cikupa candidate location can be seen in Fig 3.

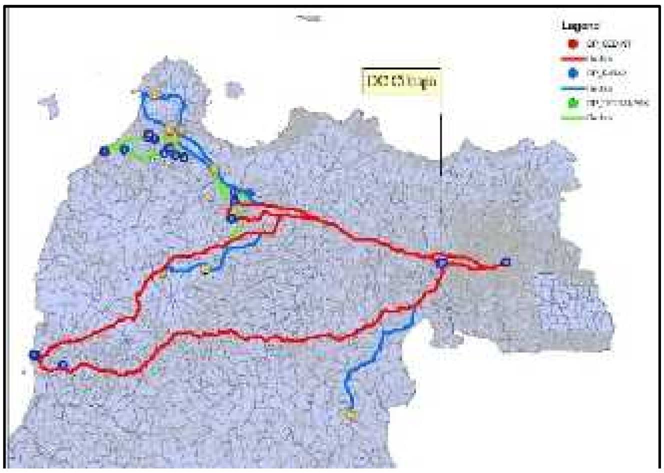

Fig 3. Distribution Routes with DC in Cikupa

For the Cikupa location candidate, the routing analysis yielded three distinct routes corresponding to three different scenarios. The routing outcomes, in conjunction with the cargo capacity achievable when utilizing a distribution center situated in Cikupa, are detailed in Table 11. It is noteworthy that the average distance covered across these three scenarios, originating from the current distribution center location, amounts to 387.79 kilometers.

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Table 11. Routing Details with the Distribution Center in Cikupa

No	Routes	Quantity (kg)	Distance (km)
	Routes with the Most Demand Points		
1	DC - Harjatani - Cibeber - Ciwedus - Randakari - Gunungsugih - Kebonsari - DC	1430	146,57
2	DC - Kramatwatu - Ciwaduk - Lopang - DC	1540	118,22
3	DC - Citangkil - Warnasari - Tamansari - DC	1705	153,70
4	DC - Cikupa - DC	1500	0
5	DC - Cikupa - DC	2000	0
6	DC - Cikupa - DC	2000	0
	Total	10175	418,49
	Routes with Average Demand Points		
1	DC - JombangWetan - DC	2000	116,49
2	DC - Gedong Dalem - Mekarsari - Kebondalem	1980	144,97
3	DC - JombangWetan - Kramatwatu - DC	1355	116,83
4	DC - Tamansari - Panyaungan Jaya - DC	1540	124,54
5	DC - Sajira - DC	1155	84,54
	Total	8030	587,38
	Route with Fewest Demand Points		
1	DC - Labuan - DC	2000	189,20
2	DC - Babakanlor - Labuan - Teluk - DC	1960	193,40
3	DC - Dalung - Serang - Bencongan Indah - DC	780	116,68
4	DC - Bencongan Indah - DC	2000	26,74
5	DC - Bencongan Indah - DC	2000	26,74
6	DC - Bencongan Indah - DC	2000	26,74
7	DC - Bencongan Indah - DC	2000	26,74
8	DC - Bencongan Indah - DC	2000	26,74
	Total	14740	632,96

Subsequently, distribution routing was executed, establishing a distribution center at the JombangWetan location. The routing outcomes associated with the JombangWetan candidate site are visually presented in Figure 4.

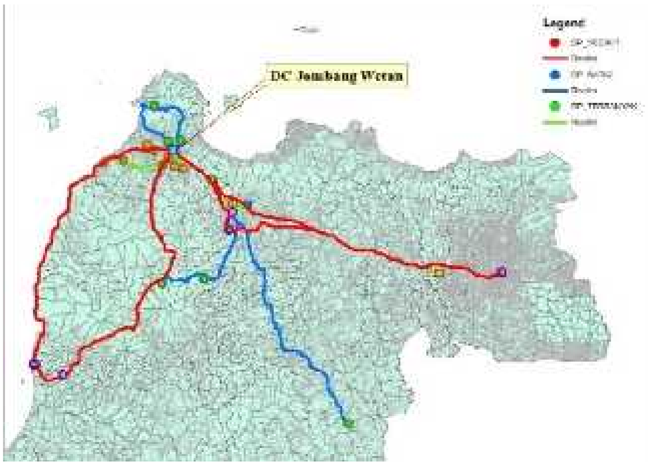

Fig 4. Distribution Routes with DC in Jombang Wetan

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Through routing analysis utilizing the JombangWetan location as the candidate site, three distinct routes were generated based on the three previously selected daily data samples. The routing outcomes, inclusive of the cargo capacity achievable when utilizing a distribution center situated in JombangWetan, are comprehensively documented in Table 12. Notably, the average distance traveled across these three scenarios, originating from the current distribution center location, amounts to 363.26 kilometers.

Table 12. Routing Details with the Distribution Center in Jombang Wetan

No	Routes	Quantity(kg)	Distance (km)
	Routes with the Most Demand Points		
1	DC - Cikupa - DC	2000	116,49385
2	DC - Cikupa - DC	2000	116,49385
3	DC - Ciwedus - Randakari - Gunungsugih - Citangkil - Warnasari - Kebonsari - DC	1870	32,829668
4	DC - Ciwaduk - DC	1155	4,460563
5	DC - Cibeber - Harjatani - Tamansari - DC	1265	70,799946
6	DC - Kramatwatu - Cikupa - Lopang - DC	1885	118,16214
	Total	10175	459,24002
	Routes with Average Demand Points		
1	DC - Panyaungan Jaya - Tamansari - DC	1540	77,137906
2	DC - Sajira - Kramatwatu - DC	1320	141,978
3	DC - Gedong Dalem - Mekarsari - Kebondalem - DC	1980	32,868774
4	DC - JombangWetan - DC	1190	0
5	DC - JombangWetan - DC	2000	0
	Total	8030	251,98468
	Route with Fewest Demand Points		
1	DC - Bencongan Indah - DC	2000	139,42314
2	DC - Bencongan Indah - DC	2000	139,42314
3	DC - Bencongan Indah - DC	2000	139,42314
4	DC - Bencongan Indah - DC	2000	139,42314
5	DC - Bencongan Indah - DC	2000	139,42314
6	DC - Labuan - DC	2000	121,78889
7	DC - Teluk - Labuan - Babakanlor - DC	1960	132,79524
8	DC - Bencongan Indah - Dalung - Serang - DC	780	147,88025
	Total	14740	1099,5801

Routes with the Most Demand Points

No	Routes	Quantity (kg)	Distance (km)
1	DC - Cikupa - DC	2000	116,49
2	DC - Cikupa - DC	2000	116,49
3	DC - Ciwedus - Randakari - Gunungsugih – Citangkil - Warnasari - Kebonsari - DC	1870	32,83
4	DC - Ciwaduk - DC	1155	4,46
5	DC - Cibeber - Harjatani - Tamansari - DC	1265	70,80
6	DC - Kramatwatu - Cikupa - Lopang - DC	1885	118,16
	Total	10175	459,24

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	Routes with Average Demand Points		
1	DC - Panyaungan Jaya - Tamansari - DC	1540	77,14
2	DC - Sajira - Kramatwatu - DC	1320	141,98
3	DC - Gedong Dalem - Mekarsari - Kebondalem - DC	1980	32,87
4	DC – Jombang Wetan - DC	1190	0
5	DC – Jombang Wetan - DC	2000	0
	Total	8030	251,98
	Route with Fewest Demand Points		
1	DC - Bencongan Indah - DC	2000	139,42
2	DC - Bencongan Indah - DC	2000	139,42
3	DC - Bencongan Indah - DC	2000	139,42
4	DC - Bencongan Indah - DC	2000	139,42
5	DC - Bencongan Indah - DC	2000	139,42
6	DC - Labuan - DC	2000	121,79
7	DC - Teluk - Labuan - Babakanlor - DC	1960	132,80
8	DC - Bencongan Indah - Dalung - Serang - DC	780	147,88
	Total	14740	1099,58

In the final phase, the distribution routing process is undertaken, establishing a distribution center at the Bencongan Indah site. Detailed routing results about the BenconganIndah candidate location are depicted in Figure 5.

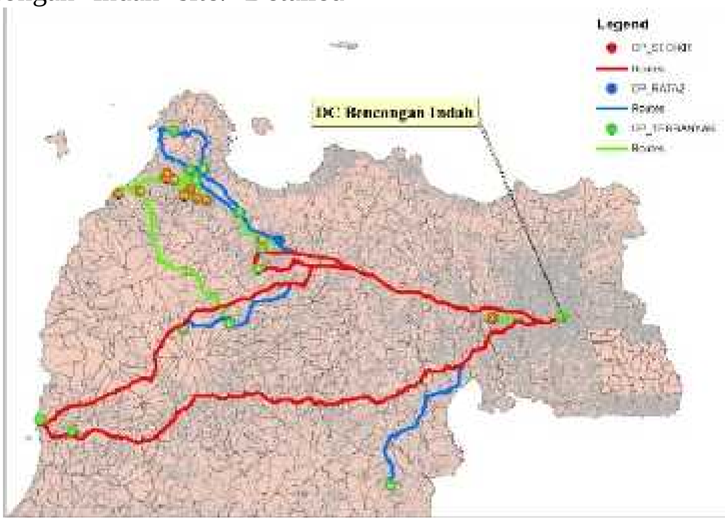

Fig 5. Distribution Routes with DC in Bencongan Indah

Through the routing analysis conducted using Bencongan Indah as the candidate site, three distinct routes were derived based on the previously selected daily data samples. The routing outcomes, in conjunction with the cargo capacity attainable for the distribution center located in Bencongan Indah, are presented comprehensively in Table 13. Notably, the average distance covered across these three scenarios, starting from the current distribution center location, amounts to 473.77 kilometers.

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Table 13. Routing Details with Distribution Center in Bencongan Indah

No	Routes	Quantity (kg)	Distance (km)
	Routes with the Most Demand Points		
1	DC - Ciwaduk - DC	1155	139,476061
2	DC - Cikupa - DC	1500	26,73612195
3	DC - Cikupa - DC	2000	26,73612195
4	DC - Kramatwatu - Warnasari - Citangkil - Ciwedus - Cibeber - Harjatani - DC	1980	155,6513095
5	DC - Tamansari - Randakari - Gunungsugih - Kebonsari - Lopang - DC	1540	188,4615738
6	DC - Cikupa - DC	2000	26,73612195
	Total	10175	563,7973102
	Routes with Average Demand Points		
1	DC - JombangWetan - DC	2000	139,4231366
2	DC - Gedong Dalem - Mekarsari - Kebondalem - DC	1980	167,895004
3	DC - JombangWetan - Kramatwatu - DC	1355	139,76065
4	DC - Tamansari - Panyaungan Jaya - DC	1540	147,474793
5	DC - Sajira - DC	1155	107,0029329
	Total	8030	701,5565165
	Route with Fewest Demand Points		
1	DC - Labuan - DC	2000	212,133526
2	DC - Babakanlor - Labuan - Teluk - DC	1960	216,9896324
3	DC - Dalung - Serang - DC	220	114,7800153
4	DC - Bencongan Indah - DC	560	0
5	DC - Bencongan Indah - DC	2000	0
6	DC - Bencongan Indah - DC	2000	0
7	DC - Bencongan Indah - DC	2000	0
8	DC - Bencongan Indah - DC	2000	0
9	DC - Bencongan Indah - DC	2000	0
	Total	14740	543,9031736

Consequently, the obtained outcomes can be succinctly summarized by Table 14, facilitating a comparative analysis of the travel distances for each route depicted in Figure 6 below.

Table 13. Route Length / Travel Distance Comparison

	Baseline	**Relocation: Cikupa**	**Relocation: Jombang Wetan**	**Relocation: Bencongan Indah**
Route Length on the Day with the Most Demand Points (km)	400,23	418,49	459,24	563,80
Difference (km)		**18,26**	**59,01**	**163,57**
Route Length on Day with Average Demand Points (km)	305,52	587,38	251,98	701,56
Difference (km)		**281,86**	**-53,54**	**396,03**
Route Length on the Day with the Fewest Demand Points (km)	881,10	632,96	1099,58	543,90
Difference (km)		**-248,14**	**218,48**	**-337,20**
Average Route Length of Three Scenarios (km)	528,95	387,79	363,26	473,77
Difference (km)		**-141,16**	**-165,70**	**-55,18**

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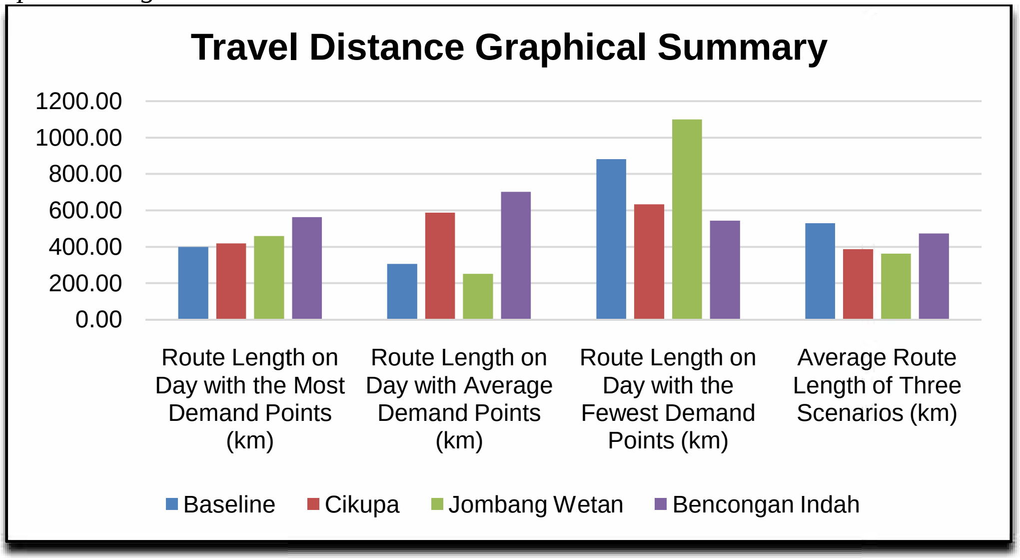

Fig 6. Travel Distance Graphical Summary

Based on the preceding comparative analysis, it is evident that, on the day characterized by the highest demand points, the current baseline scenario already exhibits the shortest travel distance. However, when confronted with a day featuring average demand points, the most favorable position with the shortest travel distance is secured by the company if it relocates to Jombang Wetan. Conversely, on a day characterized by the lowest demand points, Bencongan Indah emerges as the distribution center location yielding the shortest travel distance. Upon averaging the travel distances across these three routing scenarios, it becomes apparent that all proposed relocation sites outperform the baseline scenario, as each of them offers shorter distances. Nonetheless, when considering this average route length, the most recommendable relocation point is Jombang Wetan. This choice is substantiated by the fact that relocating to Jombang Wetan, on average, results in a reduction of 31.33% in travel distance, or an average savings of 165.7 kilometers compared to the baseline scenario. These savings surpass that achieved by relocating to Cikupa, which yields an average mileage reduction of only 10.43%, and Bencongan Indah, which achieves an average mileage reduction of 26.69%. The relocation to Jombang Wetan is thus preferred due to its potential to enhance the efficiency of the product distribution process.

I. CONCLUSION

Based on the conducted data processing and analysis, two primary conclusions can be drawn as follows: Utilizing the P-Median method for determining the optimal location of the new distribution center, it is advisable to consider relocating the distribution center to the Cikupa area when analyzing data with the highest demand points, the Jombang Wetan area when dealing with data reflecting average demand points, or the Bencongan Indah area for data featuring the lowest demand points.

On average, all three of these relocation options present more favorable routing scenarios than the baseline scenario, as they consistently exhibit shorter travel distances. Among these alternatives, Jombang Wetan emerges as the most advantageous relocation point, given its capacity to yield the greatest mileage savings (31.33% or 165.7 kilometers) when compared to other scenarios.

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