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DETERMINATION OF TEXTILE PRODUCT DISTRIBUTION ROUTES USING THE CAPACITATED VEHICLE ROUTING PROBLEM WITH TIME WINDOWS (CVRPTW) APPROACH

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Time Windows

Abstrak

Penelitian ini dilatarbelakangi oleh permasalahan distribusi produk tekstil pada PT XYZ yang belum menerapkan rute pengiriman secara optimal, sehingga berdampak pada tingginya jarak tempuh serta waktu yang diperlukan dalam proses distribusi. Penelitian ini bertujuan untuk memperoleh rute distribusi yang optimal dengan menerapkan metode Capacitated Vehicle Routing Problem with Time Windows (CVRPTW). Data yang digunakan dalam penelitian meliputi permintaan customer, kapasitas kendaraan, matriks jarak, matriks waktu tempuh, service time, serta batas waktu pelayanan customer. Penyusunan model matematis dilakukan menggunakan pendekatan Mixed Integer Linear Programming (MILP), kemudian disimulasikan melalui Google Colab dengan menggunakan bahasa pemrograman Python dan software PuLP Solver. Berdasarkan hasil penelitian, penerapan metode CVRPTW menghasilkan rute distribusi yang lebih optimal dibandingkan dengan rute existing perusahaan. Hal tersebut ditunjukkan melalui penurunan total jarak tempuh dari 5.466 km menjadi 3.155 km serta total waktu distribusi dari 4.755 menit menjadi 3.093 menit. Dengan demikian, penerapan CVRPTW dapat meningkatkan efisiensi proses distribusi melalui pengurangan jarak tempuh dan waktu distribusi.

Keywords:
Distribution;
Mixed Integer Linear Programming;
Phyton;
Route Optimization;
Time Windows

Abstract

This study was initiated by the distribution problem of textile products at PT XYZ, where the delivery routes have not been optimized, resulting in considerable travel distances and distribution times. The objective of this study is to obtain optimal distribution routes by applying the Capacitated Vehicle Routing Problem with Time Windows (CVRPTW) method. The data utilized in this study consist of customer demand, vehicle capacity, distance matrix, travel time matrix, service time, and customer service time limits. The mathematical model was formulated using the Mixed Integer Linear Programming (MILP) approach and subsequently simulated through Google Colab using the Python programming language and PuLP Solver software. The findings demonstrate that the CVRPTW method produces more optimal distribution routes than the company's existing routes.

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This is evidenced by the decrease in total travel distance from 5,466 km to 3,155 km and in total distribution time from 4,755 minutes to 3,093 minutes. Therefore, the implementation of CVRPTW can improve distribution efficiency by reducing both travel distance and distribution time.

1. INTRODUCTION

Increasingly intense competition in the industrial sector requires companies to improve the effectiveness of their operational activities in order to maintain competitiveness. One aspect that plays an important role in business success is the ability to manage distribution systems effectively (Apriani Pratiwi & Novalia Harahap, 2024). The implementation of a good distribution system enables companies to deliver products to customers on time and according to predetermined requirements.

Distribution is an important component of the supply chain because it is directly related to the activity of delivering products from companies to customers (Hidayat & Mulyono, 2025). The success of the distribution process is determined not only by the quality of the products produced, but also by the company's ability to design efficient delivery patterns (Putri et al., 2023). Suboptimal distribution management can result in increased vehicle travel distances, longer delivery times, and higher transportation operating costs.

PT XYZ is a company engaged in textile production and distributes products to a number of customers across Java Island. In practice, the distribution system implemented by the company has not utilized route optimization methods, resulting in relatively inefficient travel to several customers. This condition is indicated by exclusive routes and separate fleet trips, even though some customers are located relatively close to one another. In addition, the distribution process needs to consider vehicle capacity and the delivery time limits of each customer so that shipments can be carried out according to the established schedule.

The problem of determining distribution routes is one of the problems included in the Vehicle Routing Problem (VRP) field. VRP is a distribution optimization problem concerned with determining vehicle travel routes to serve a number of customers optimally (Azizah & Herlina, 2022). One development of VRP is the Capacitated Vehicle Routing Problem with Time Windows (CVRPTW), which accommodates both vehicle capacity limitations and customer service time limits. Considering these conditions, this study aims to obtain optimal textile product distribution routes by taking vehicle capacity and service time into account, while also determining the effect of the proposed routes on the company's distribution cost efficiency.

Based on the problems identified in the company's distribution system, this study focuses on optimizing distribution routes using the Capacitated Vehicle Routing Problem with Time Windows (CVRPTW) method with a Mixed Integer Linear Programming (MILP) approach. The problems examined in this study are how to obtain optimal textile product distribution routes at PT XYZ while considering time windows, and how distribution costs compare between the initial routes and the proposed routes in terms of distribution efficiency. This study aims to determine optimal distribution routes and analyze distribution cost efficiency between the existing condition and the proposed routes at PT XYZ. Theoretically, this study is expected to provide additional references and support the development of studies related to distribution optimization using the MILP-based CVRPTW method. Practically, the results are expected to serve as a consideration for the company in making distribution decisions so that travel distance, distribution time, and distribution operating costs can be improved efficiently.

Several previous studies have examined distribution route optimization problems using the Vehicle Routing Problem (VRP) approach for various applications and with different methods. Borman & Oktavia (2021) showed that the One Vehicle Routing Problem (OVRP) method can produce optimal distribution routes with a total travel distance of 130 km using LINGO software. Mafaza & Muslim (2023), who applied the Capacitated Vehicle Routing Problem (CVRP) method, obtained a 17.7% reduction in transportation costs and an 18.5% reduction in travel distance. Meanwhile, Alfiansah & Abdulrahim (2023) showed that the application of VRP could reduce styrofoam product delivery costs to Rp2,946,368 per month. Azizah & Herlina (2022) also found that the VRP method could reduce distribution travel distance by 15.9% while lowering delivery operating costs by 16%. Furthermore, Khoidir et al. (2025) demonstrated that the Mixed Integer Linear Programming (MILP) approach can be effectively used to minimize total distribution costs in multi-product supply chain networks. Nugroho & Abdulrahim (2022) obtained a 24% reduction in snack-food distribution travel distance through the application of the Saving Matrix method. Based on these studies, it can be concluded that the VRP approach has the potential to improve distribution efficiency. However, most previous studies have focused on minimizing distribution distance and costs and have not specifically integrated customer service time limits or time windows. Therefore, this study develops a Mixed Integer Linear Programming (MILP)-based CVRPTW approach by integrating vehicle capacity and time-window considerations to obtain a more optimal distribution system.

2. METHOD

This study applies the Vehicle Routing Problem (VRP) method as an approach to solving distribution problems. VRP is an optimization problem used to determine optimal vehicle routes for serving a number of customers from a depot and then returning to the depot (Nugroho & Abdulrahim, 2022). Basically, VRP concerns determining travel patterns that can efficiently serve all *customers*, thereby minimizing travel distance, travel time, and distribution costs.

The VRP model can be developed into several forms according to the characteristics and conditions of the distribution problem being addressed. One such development is the Capacitated Vehicle Routing Problem with Time Windows (CVRPTW) (Ketaren et al., 2025). CVRPTW is a distribution optimization model that incorporates vehicle capacity and customer service time limits into the route determination process (Zidanne et al., 2025). In its application, each vehicle has a maximum carrying capacity that must be satisfied during distribution activities. On the other hand, each customer has a specific time range for receiving goods, so vehicle arrivals must be adjusted to the established service times.

The application of CVRPTW allows the resulting distribution system to better reflect operational conditions and become more efficient because several distribution constraints can be considered simultaneously. Thus, route determination is not only aimed at minimizing vehicle travel distance, but also at ensuring timely deliveries and optimal utilization of fleet capacity.

The CVRPTW model in this study is solved using a Mixed Integer Linear Programming (MILP) approach. MILP is a mathematical optimization approach that uses a linear objective function and constraints and includes decision variables that can be integer or binary values (Ramadhani et al., 2021). MILP was selected because it can systematically handle distribution problems involving multiple constraints and thereby obtain an optimal solution. The optimization process is carried out using the Python programming language through the Google Colab platform. Google Colab is a cloud-based programming environment that allows Python code to be executed without requiring additional software installation on the user's computer (Maharani, 2025).

The formulation and solution of the optimization model in this study are carried out using the PuLP library. PuLP is a Python library used to build *linear programming* and integer programming models. Through this library, decision variables, objective functions, and constraints in the mathematical model can be defined systematically using Python syntax. In the CVRPTW model used in this study, PuLP is utilized to formulate the objective function for minimizing distribution costs and vehicle travel distance and to construct constraints related to vehicle capacity, customer time windows, and distribution route continuity.

After the mathematical model is formulated using PuLP, the optimal solution is obtained with the assistance of the CBC solver. CBC is a Mixed Integer Linear Programming-based optimization solver used to solve integer programming and binary programming problems. During the search for a solution, the solver uses branch-and-bound and cutting-plane methods to obtain the best combination of decision variables that satisfies all model constraints while minimizing the objective function.

The use of Google Colab, PuLP, and the CBC solver enables distribution optimization to be performed more effectively because large amounts of distribution data can be processed and distribution routes can be generated automatically. This approach also facilitates the analysis and development of more complex distribution optimization models according to the company's needs. The research data consist of primary and secondary data. Primary data were obtained through direct observation and interviews related to the company's distribution activities, while secondary data were obtained from company documents related to the distribution process. The data used in this study include:

1). Distribution customer data
2). Customer demand data
3). Vehicle capacity data
4). Number of distribution vehicles
5). Distance data between customers
6). Distribution travel-time data
7). Customer service-time data
8). Customer time-window data
9). Fuel cost data

The formulated mathematical model was subsequently executed using Python through the Google Colab platform to obtain the optimal proposed distribution routes. The results obtained from the optimization process were then compared with the existing distribution system based on total travel distance and distribution time. This comparison was conducted to determine the efficiency level that could be achieved through the implementation of the optimized distribution routes.

Indices represent the elements contained in the distribution model, such as customers, the depot, and the vehicle fleet (Sari et al., 2020). The use of indices aims to simplify the mathematical formulation of CVRPTW so that the relationships among locations in distribution activities can be represented systematically. The indices used are defined as follows:

i = index representing customer i
j = index representing customer j
K = index representing the fleet
C = index representing delivery cost
d = index representing demand quantity
Ds = index representing the distance between customers
w = index representing the maximum fleet capacity
E = index representing vehicle fuel cost per km
T = index representing the initial service-time limit
a = index representing the earliest service time
b = index representing the latest service time
I = index representing vehicle loading/unloading time
S = index representing delivery duration

Parameters are quantities with predetermined values that are used in the CVRPTW mathematical model to represent the conditions of the company's distribution system (Fatma et al., 2022). The parameters used in this study consist of d_ij, representing the travel distance from point i to point j in kilometers; t_ij, representing travel time in minutes; q_i, representing customer demand; Q_k, representing the maximum fleet capacity; c_ij, representing distribution cost; a_i, representing the earliest customer service time; b_i, representing the latest customer service time; s_i, representing loading/unloading or customer service time; and M, representing a sufficiently large number used in the time constraint of the Mixed Integer Linear Programming (MILP) model.

d_{ij} = travel distance from point to point in kmij
t_{ij} = travel time from point to point in minutesij
q_i = customer demand in rolls$i$
Q_k = maximum fleet carrying capacity$k$
c_{ij} = distribution cost from point to pointij
a_i = earliest customer service time$i$
b_i = latest customer service time$i$
s_i = loading/unloading time or customer service time$i$
M = large number used for the time constraint in the MILP model

The objective function in this study aims to minimize the total vehicle travel distance during the distribution process. Minimizing travel distance is intended to improve distribution efficiency, thereby reducing travel time and the company's operating costs. The objective function for minimizing total distance can be formulated as follows:

$$\text{Minimize } Z_1 = \sum_{k \in K} \sum_{i \in N} \sum_{j \in N, i \neq j} d_{ij} \cdot x_{ijk} \qquad (1)$$

Description:

- Z_1 = total distribution distance
- d_{ij} = distance from point to pointij
- x_{ijk} = vehicle travel decision variable
- N = set of all points
- K = set of vehicles

The objective function aims to reduce the total kilometers traveled by the fleet so that delivery costs can be minimized.

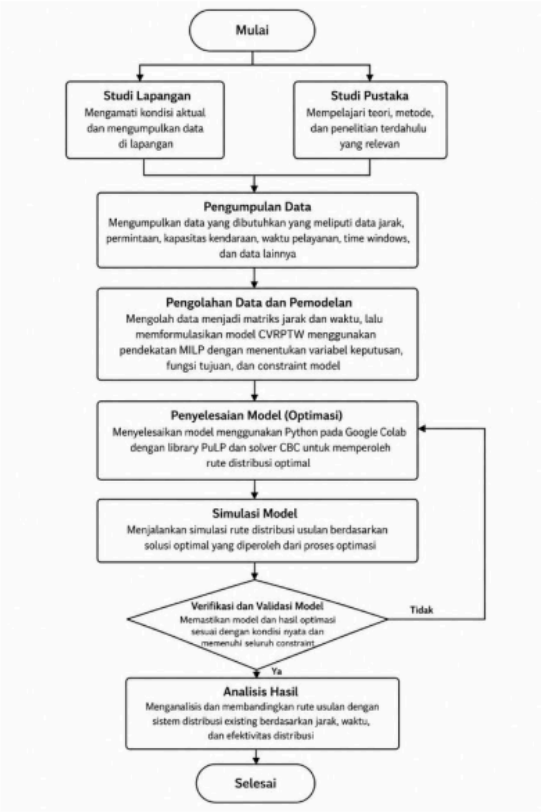


Figure 1. Research Flowchart

3. RESULTS AND DISCUSSION

3.1 Data Collection

Table 1. Distance and Demand Data

No	Code	Distance	Demand (Rolls)
1	R1	511	38
2	R2	599	31
3	R3	36	26
4	R4	550	33
5	R5	614	28
6	R6	41	27
7	R7	619	33
8	R8	4	30
9	R9	594	36
10	R10	610	24
11	R11	22	31
12	R12	623	31
13	R13	534	33
14	R14	250	29
	Total		430

Data collection was conducted by identifying the quantity of product demanded by each customer. Customer demand data are used to determine the total distribution requirements that must be fulfilled by the company, while distance data are used as one of the main parameters in the distribution route optimization process.

Distances between customers were obtained through Google Maps, using the company location as the distribution point and the respective customer locations.

Table 2. Fleet Capacity Data

Fleet Type	Maximum Fleet Load	Maximum Box Capacity	Number of Vehicles
Box Truck	6 ton	150 rol	1
Box Truck	6 ton	150 rol	1
Box Truck	6 ton	150 rol	1

Distribution fleet data are used to determine the number of available vehicles and the maximum load capacity that can be carried by each vehicle. Vehicle capacity is an important constraint in the CVRPTW model because the total demand of customers served on a route must not exceed the capacity of the vehicle used.

Table 3. Distance Matrix Data

	X	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14
X	0	511	599	36	550	614	41	619	4	594	610	22	623	534	250
R1	511	0	186	492	130	189	505	181	489	154	181	471	193	124	640
R2	599	186	0	600	63	12	613	7	598	63	9	579	10	71	766
R3	36	493	600	0	551	603	15	595	39	568	595	24	607	538	238
R4	550	130	63	551	0	79	564	71	549	38	71	530	74	5	716
R5	614	189	12	603	79	0	616	9	601	76	7	582	12	74	769
R6	41	505	613	15	564	616	0	610	51	583	610	38	623	550	253
R7	619	181	7	595	71	9	610	0	592	68	5	574	16	66	760
R8	4	489	598	39	549	601	51	592	0	563	591	23	603	535	234
R9	594	154	63	568	38	76	583	68	563	0	66	547	69	37	734
R10	610	181	9	595	71	7	610	5	591	66	0	573	587	66	760
R11	22	471	579	24	530	582	38	574	23	547	573	0	584	516	215
R12	623	193	10	607	74	12	623	16	603	69	587	584	0	78	773
R13	534	124	71	538	5	74	550	66	535	37	66	516	78	0	703
R14	250	640	766	238	716	769	253	760	234	734	760	215	773	703	0

The distance matrix was constructed based on distance data between customers and the distribution depot obtained through Google Maps. The matrix is used to determine travel distances between distribution points, which then serve as one of the main parameters in the route optimization process using the CVRPTW method. Each value in the matrix represents the travel distance from one location to another in kilometers. The distance matrix was prepared to facilitate the calculation of total vehicle travel distance during the distribution process.

Table 4. Travel-Time Matrix Data

	X	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14
X	0	417	510	67	463	505	81	501	10	478	499	34	519	455	218
R1	417	0	191	401	144	202	413	197	350	162	196	376	203	140	516
R2	510	191	0	526	85	33	543	23	541	80	25	506	26	86	638
R3	67	401	526	0	435	489	20	478	58	428	465	50	486	444	220
R4	463	144	85	435	0	98	466	88	495	72	87	480	92	15	590
R5	505	202	33	489	98	0	525	20	515	95	18	500	25	94	640

R6	81	413	543	20	466	525	0	520	75	500	520	65	535	461	230
R7	501	197	23	478	88	20	520	0	510	90	15	495	28	90	635
R8	10	350	541	58	495	515	75	510	0	490	505	48	515	460	215
R9	478	162	80	428	72	95	500	90	490	0	88	485	90	56	610
R10	499	196	25	465	87	18	520	15	505	88	0	495	505	90	635
R11	34	376	506	50	480	500	65	495	48	485	495	0	500	425	205
R12	519	203	26	486	92	25	535	28	515	90	505	500	0	100	645
R13	455	140	86	444	15	94	461	90	460	56	90	425	100	0	572
R14	218	516	638	220	590	640	230	635	215	610	635	205	645	572	0

The travel-time matrix was constructed based on estimated travel times between customers and the distribution depot. Travel-time data were obtained through Google Maps while considering travel conditions during the distribution process. In the CVRPTW model, the time matrix is used to ensure that deliveries can be made within customer service time limits (time windows). Each value in the matrix represents the estimated travel time from one location to another in minutes and can therefore be used to calculate the overall vehicle distribution time.

Table 5. Initial Route Data

No	Fleet	Initial Route	Demand (Rolls)	Distance (km)	Time (minutes)
1	Box Truck = Capacity 6 ton/150 rol	Factory-PT JJ GLOVES(R11)-CV Celindo Putra (R1)-PT Kemilau Karya Bersama(R4)-Factory	102	1173	1017
		Factory-PT Dunia Material Sepatu(R10)-PT Prima Niaga(R13)-Factory	57	1210	1044
2	Box Truck = Capacity 6 ton/150 rol	Factory-PT LANGGENG JAYA(R2)-PT Makmur Nusantara (R5)-PT Suntex(R7)-Factory	92	1239	1064
		Factory-CV Sinar Maju Bersama (R9)-PT Joa Industries(R12)-Factory	67	1286	1087
3	Box Truck = Capacity 6 ton/150 rol	Factory-CV Hancover (R14)-PT Eagle Gloves (R3)-PT Samku (R6)-PT Woneel GK (R8)-Factory	112	558	543
Total			430	5466	4755

The initial distribution routes represent the existing distribution system implemented by the company before optimization. Under the existing condition, distribution activities still follow previously established delivery patterns, resulting in several customers being served through inefficient trips and exclusive routes. The initial route data are used as a reference for comparing distribution conditions before and after optimization using the CVRPTW method.

Table 6. Initial Distribution Cost Data

No	Fleet	Loaded Departure Distance (km)	Empty-Load Distance (km)	Fuel Cost
1	Box Truck = Capacity 6 ton/150 rol	623	550	Rp1,121,622

		676	534	Rp1,169,600
2	Box Truck = Capacity 6 ton/150 rol	620	619	Rp1,170,356
		663	623	Rp1,222,111
3	Box Truck = Capacity 6 ton/150 rol	554	4	Rp630,889
Total		3136	2330	Rp5,314,578

The initial distribution cost data are used to determine the total operating costs incurred under the company's existing system. Fuel costs are incurred to meet the fleet's fuel requirements during distribution activities. Fuel costs are influenced by vehicle travel distance, vehicle fuel consumption rate, and the price of the fuel used. The distribution fleet uses diesel fuel priced at Rp6,800 per liter, with an average consumption rate of 6 km/liter when the vehicle is loaded and 9 km/liter when the vehicle is unloaded.

3.2 Mathematical Model Development

Data processing begins with constructing the CVRPTW mathematical model based on Mixed Integer Linear Programming (MILP). The mathematical model consists of an objective function and constraints used to determine optimal distribution routes. The objective function in this study is to minimize total vehicle travel distance. Meanwhile, the model constraints include vehicle capacity, customer time-window limits, vehicle route continuity, and the requirement that each customer can only be served once.

```
#================================
# FUNGSI TUJUAN
#================================

model += lpSum(
    dist[i][j] * x[(i, j, k)]
    for i in nodes for j in nodes for k in vehicles if i != j
)
```

The objective function in the CVRPTW model in this study is used to minimize total vehicle travel distance during the distribution process. Minimizing travel distance aims to improve distribution efficiency by reducing fuel consumption, travel time, and the operating costs incurred by the company. Constraints are applied to ensure that the optimization solution remains consistent with actual distribution conditions. The constraints used in the CVRPTW model in this study include:

```
#================================
# KENDALA MODEL
#================================
# 1. Setiap customer dikunjungi tepat satu kali
for j in customers:
    model += lpSum(
        x[(i, j, k)]
        for i in nodes for k in vehicles if i != j
    ) == 1
# 2. Setiap customer ditinggalkan tepat satu kali
for i in customers:
    model += lpSum(
        x[(i, j, k)]
        for j in nodes for k in vehicles if i != j
    ) == 1
```

```
# 3. Armada berangkat dari pabrik
for k in vehicles:
    model += lpSum(
        x[(0, j, k)]
        for j in customers
    ) == 1
# 4. Armada kembali ke pabrik
for k in vehicles:
    model += lpSum(
        x[(i, 0, k)]
        for i in customers
    ) == 1

# 5. Keseimbangan aliran
for k in vehicles:
    for h in customers:
        model += lpSum(
            x[(i, h, k)]
            for i in nodes if i !=h
        ) == lpSum(
            x[(h, j, k)]
            for j in nodes if j !=h
        )
# 6. Kapasitas armada
for k in vehicles:
    model += lpSum(
        demand[i] * lpSum(x[(i, j, k)] for j in nodes if i != j)
        for i in customers
    ) <= capacity[k]
# 7. Waktu awal di pabrik
for k in vehicles:
    model += t[(0, k)] == 0
# 8. Kendala urutan waktu
for k in vehicles:
    for i in nodes:
        for j in customers:
            if i != j:
                model += t[(j, k)] >= (
                    t[(i, k)] + service[i] + travel[i][j]
                    - M * (1 - x[(i, j, k)])
                )
# 9. Kendala time windows
for k in vehicles:
    for i in customers:
        dikunjungi_armada_k = lpSum(
            x[(i, j, k)]
            for j in nodes if i !=j
        )

      model += t[(i, k)] >= earliest[i] - M * (1 - dikunjungi_armada_k)
            model += t[(i, k)] <= latest[i] + M * (1 - dikunjungi_armada_k)
```

Constraints are used to ensure that the optimization solution remains consistent with actual conditions in the company's distribution process. The constraints applied in this study include the requirements that each customer must be visited and departed from exactly once, vehicles must depart from and return to the factory, vehicle route balance, fleet capacity, vehicle departure time, travel-time sequence, and customer service time limits (time windows). Applying these constraints enables the CVRPTW model to produce distribution routes that are more realistic, structured, and consistent with the company's operational conditions.

3.3 Model Verification and Validation

DISTRIBUTION ROUTE OPTIMIZATION RESULTS
Solution Status: Optimal
FLEET 1

The route obtained for Fleet 1 is Factory (02:00) - R4 (09:43) - R13 (10:13) - R5 (12:04) - R7 (12:38) - R10 (13:10) - Factory (21:41). Fleet 1 carries a total load of 148 rolls or 5,920 kg. The arrival times and quantities unloaded at each customer are detailed as follows:

R4 | Arrival time: 09:43 | Unloaded: 30 rolls / 1,200 kg
R13 | Arrival time: 10:13 | Unloaded: 33 rolls / 1,320 kg
R5 | Arrival time: 12:04 | Unloaded: 28 rolls / 1,120 kg
R7 | Arrival time: 12:38 | Unloaded: 33 rolls / 1,320 kg
R10 | Arrival time: 13:10 | Unloaded: 24 rolls / 960 kg
Total distance traveled by Fleet 1 is 1,253 km, with a total travel time of 1,181 minutes.

FLEET 2

The route obtained for Fleet 2 is Factory (02:00) - R8 (09:00) - R6 (10:34) - R3 (11:08) - R11 (12:11) - R14 (15:52) - Factory (19:45). Fleet 2 carries a total load of 150 rolls or 6,000 kg. The arrival times and quantities unloaded at each customer are detailed as follows:

R8 | Arrival time: 09:00 | Unloaded: 37 rolls / 1,480 kg
R6 | Arrival time: 10:34 | Unloaded: 27 rolls / 1,080 kg
R3 | Arrival time: 11:08 | Unloaded: 26 rolls / 1,040 kg
R11 | Arrival time: 12:11 | Unloaded: 31 rolls / 1,240 kg
R14 | Arrival time: 15:52 | Unloaded: 29 rolls / 1,160 kg
Total distance traveled by Fleet 2 is 559 km, while the total required travel time is 655 minutes.

FLEET 3

The route obtained for Fleet 3 is Factory (02:00) - R2 (10:30) - R12 (11:12) - R9 (12:58) - R1 (15:47) - Factory (22:57). Fleet 3 carries a total load of 102 rolls or 4,080 kg. The arrival times and quantities unloaded at each customer are detailed as follows:

R2 | Arrival time: 10:30 | Unloaded: 31 rolls / 1,240 kg
R12 | Arrival time: 11:12 | Unloaded: 31 rolls / 1,240 kg
R9 | Arrival time: 12:58 | Unloaded: 14 rolls / 560 kg
R1 | Arrival time: 15:47 | Unloaded: 26 rolls / 1,040 kg
Total distance traveled by Fleet 3 is 1,343 km, with a total travel time of 1,257 minutes.

The verification stage was conducted to ensure that the mathematical model and optimization program developed were operating according to the formulated CVRPTW formulation. Based on the program run using Python in Google Colab with the PuLP library and CBC solver, the solution status obtained was “Optimal.” This indicates that the model successfully obtained the best solution based on the specified objective function and constraints. The simulation results also show that all customers were visited exactly once by the distribution fleet, each vehicle departed from and returned to the factory, and the load on each vehicle did not exceed the fleet's maximum capacity. In addition, vehicle arrival times at each customer remained within the specified time windows. Thus, all constraints in the model were satisfied.

The validation stage was conducted by comparing the distribution results obtained from the proposed model with the company's existing distribution conditions. The simulation results show that the optimization model produces more efficient distribution routes, with a total travel distance of 3,155 km and total distribution time of 3,093 minutes. These results indicate reductions in travel distance and distribution time compared with the company's existing system. Therefore, the Mixed Integer Linear Programming (MILP)-based CVRPTW model can be considered valid and used as a decision-support tool for the company's distribution activities.

3.4 Comparison of Initial and Proposed Routes

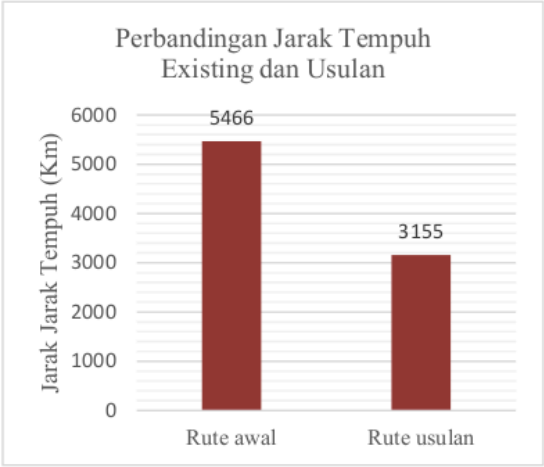


Figure 2. Travel Distance Comparison Graph

Based on the distribution travel-distance comparison graph, the application of the CVRPTW method significantly reduces total distribution distance compared with the company's existing routes. Under the existing condition, total distribution travel distance reaches 5,466 km, whereas after optimization it decreases to 3,155 km. This represents a reduction of 2,311 km, or 42.28%. The reduction occurs because the optimization model can group customers based on location proximity and determine a more efficient visit sequence, thereby making fleet routes more optimal.

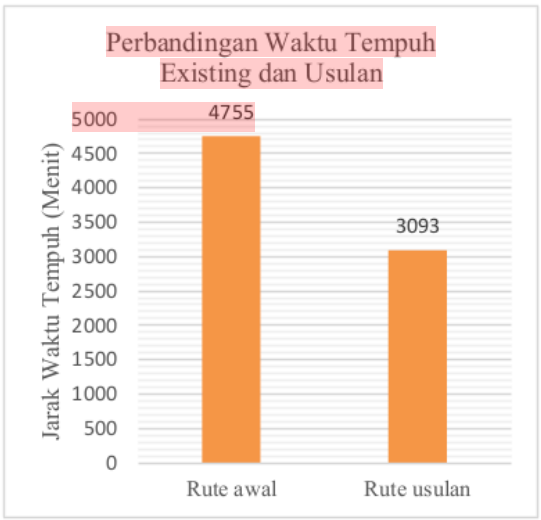


Figure 3. Travel Time Comparison Graph

Based on the distribution-time comparison graph, the application of the CVRPTW method reduces total distribution time compared with the existing system. Under the existing condition, total distribution time reaches 4,755 minutes, whereas after optimization using the CVRPTW method it decreases to 3,093 minutes. Thus, distribution time is reduced by 1,662 minutes, or 34.95%. This reduction occurs because the resulting routes eliminate inefficient trips and establish a more structured distribution sequence, thereby minimizing vehicle travel time.



Figure 4. Distribution Cost Comparison Graph

Based on the fuel-cost comparison graph, the application of the CVRPTW method demonstrates that fuel consumption costs during the company's distribution process can be reduced. Under the existing system, total fuel costs amount to Rp5,314,578, whereas under the proposed routes they decrease to Rp3,057,733. Thus, fuel-cost savings of Rp2,256,845, or 42.46%, are achieved. The reduction in fuel costs results from the decrease in total distribution travel distance, which lowers vehicle fuel consumption requirements compared with the existing distribution system.

4. CONCLUSION

The MILP-based CVRPTW method produces optimal distribution routes. Fleet 1 follows the route Factory–R4–R13–R5–R7–R10–Factory, covering 1,253 km in 1,181 minutes and carrying 148 rolls. Fleet 2 follows the route Factory–R8–R6–R3–R11–R14–Factory, covering 559 km in 655 minutes and carrying 150 rolls. Meanwhile, Fleet 3 follows the route Factory–R2–R12–R9–R1–Factory, covering 1,343 km in 1,257 minutes and carrying 102 rolls. The optimization results show that fuel costs can be reduced from Rp5,314,578 to Rp3,057,733, resulting in savings of 42.46% and improving distribution efficiency. For future research, the model can be further developed by considering multiple depots, demand uncertainty, variations in transportation capacity and costs, multiple products, and metaheuristic or hybrid approaches.

5. REFERENCES

Alfiansah, A. S., & Abdulrahim, M. (2023). *ANALISA PENENTUAN RUTE PENGIRIMAN PRODUK STYROFOAM UNTUK MEMINIMALKAN BIAYA PENGIRIMAN (STUDI KASUS : PT. MENARA CIPTA INDONESIA) Analysis of Determining Styrofoam Product Delivery Routes to Minimize Shipping Costs (Case Study PT. Menara Cipta Indonesia)*.

Apriani Pratiwi, R., & Novalia Harahap, U. (2024). *OPTIMALISASI PENDISTRIBUSIAN BARANG DENGAN MODEL MIXED INTEGER LINEAR PROGRAMMING PADA PT. LOGISTIK EKSPRESINDO UTAMA*. *7*(1), 8–15.

Borman, M. R., & Oktavia, M. (2021). One *Vehicle Routing Problem* as the Best Solution for a Hangout Catering Company Expansion Plan with Lingo Software. *Faktor Exacta*, *13*(4), 216. https://doi.org/10.30998/faktorexacta.v13i4.7540

Fatma, E., Kartika, W., & Nur Madyanti, A. (2022). Penentuan Rute Pengangkut Limbah Medis Optimal Menggunakan *Vehicle Routing Problem* with Time Window pada Kasus Multi Depot. *Jurnal Manajemen Dan Organisasi*, *13*(4), 324–335. https://doi.org/10.29244/jmo.v13i4.38587

Hidayat, D. W., & Mulyono, N. B. (2025). Optimizing Fuel Distribution Costs through *Vehicle Routing Problem* Modeling in Jakarta-Tanjung Gerem Terminals. *Jurnal Ilmiah Manajemen Kesatuan*, *13*(5), 3873–3884. https://doi.org/10.37641/jimkes.v13i5.3547

Ketaren, D. R., Gultom, P., Nasution, M. K. M., & History, A. (2025). http://ejournal.radenintan.ac.id/index.php/desimal/index Multi-objective *Vehicle Routing Problem* with time windows via genetic algorithm ARTICLE INFO ABSTRACT. *Desimal: Jurnal Matematika*, *8*(2), 195–206. https://doi.org/10.24042/djm

Khoidir, A., Firyal, B., Safitri, S., Rahmasari, D., Prodi,), & Industri, T. (2025). *OPTIMASI JARINGAN DISTRIBUSI MULTI ESELON DALAM RANTAI PASOK MULTI PRODUK MENGGUNAKAN MIXED INTEGER LINEAR PROGRAMMING*.

Mafaza, G., & Muslim, E. (2023). *Perancangan Rute Distribusi Air Minum Dalam Kemasan dengan Capacitated Vehicle Routing Problem*. https://doi.org/10.350587/Matrik

Maharani, S. (2025). PEMBANGUNAN MODEL DATA SKALA BESAR DENGAN MENGGUNAKAN BUILDER DESIGN PATTERN. *Jurnal Informatika Dan Teknik Elektro Terapan*, *13*(3). https://doi.org/10.23960/jitet.v13i3.6817

Azizah, D., & Herlina, H. (2022). *PENENTUAN RUTE DISTRIBUSI UNTUK MEMINIMALKAN BIAYA PENGIRIMAN TAS FASHION DI UD. SUWARLANDONO*.

Nugroho, R. W., & Abdulrahim, M. (2022). PENENTUAN RUTE DISTRIBUSI MAKANAN RINGAN (SNACK) DENGAN METODE *VEHICLE ROUTING PROBLEMS* (Studi kasus pada UD. NNR JAYA di Bojonegoro). *Jurnal Produktiva*, *1*(2), 7–10. https://doi.org/10.36815/jurva.v2i1.1959

Putri, A. M., Ardiansyah, M. N., & Chulasoh, B. S. (2023). Perancangan Rute Pengiriman pada PT. ABC untuk Meminimasi Tingkat Keterlambatan Pengiriman dan Biaya Transportasi Menggunakan Model Mixed Integer Linear Programming. *Jurnal Teknik Industri Terintegrasi*, *6*(4), 1387–1395. https://doi.org/10.31004/jutin.v6i4.21022

Ramadhani, D. S., Masruroh, N. A., & Waluyo, J. (2021). *Model of Vehicle Routing Problem ... (Dinda Safitri Ramadhani, et al.) MODEL OF VEHICLE ROUTING PROBLEM WITH SPLIT DELIVERY MULTI TRIPS, MULTI PRODUCTS AND COMPARTMENTS FOR DETERMINING FUEL DISTRIBUTION ROUTES*. http://journal.ugm.ac.id/index.php/ajse

Sari, G., Heryanto, R., & Santoso, S. (2020). Penentuan Rute Distribusi Menggunakan Model Integer Linear Programming dengan Metode Branch and Bound. *Go-Integratif : Jurnal Teknik Sistem Dan Industri*, *1*(01), 69–79. https://doi.org/10.35261/gijtsi.v1i01.4265

Zidanne, M., Keynobi, F., & Wirdianto, E. (2025). Jurnal Sistem Teknik Industri VRPTW Distribution Route Determination with Rigid and Flexible Time Window and Assignment Based on Number of Demand. *Jurnal Sistem Teknik Industri*, *27*(1), 14–20. https://doi.org/10.26594/register.v6i1.idarticle

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