

# The Application of Vehicle Routing Problem for Rice Distribution System in City of Bandung

Nova Indah Saragih<sup>1,\*</sup> Riski Septian Rachman<sup>1</sup>

<sup>1</sup> Department of Industrial Engineering, Faculty of Engineering, Widyatama University, Indonesia

\*Corresponding author. Email: nova.indah@widyatama.ac.id

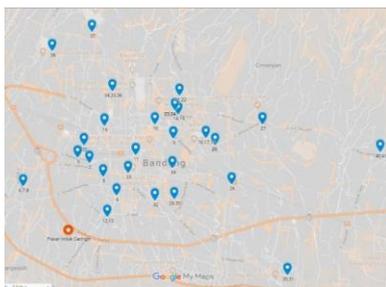
## ABSTRACT

The central market of Caringin is one of the central markets in the city of Bandung that serves traditional markets in the city, including rice. The transportation system used by the central market of Caringin to distribute rice to the traditional markets consists of direct trips. Unfortunately, direct trips cause high transportation costs. The difference of transportation cost between direct trips and tour trips can reach 19.5%. The method used in this study is the optimal method by formulating the problem as an integer linier programming (ILP) model of vehicle routing problem (VRP). The model is solved using LINGO 12.0. The results of this study are feasible vehicle routes and more efficient transportation costs. The transportation cost of direct trips is Rp41,069,529 meanwhile the transportation cost of tour trips is Rp33,988,890. The efficiency of transportation cost obtained from this study is Rp7,080,639 or 17.24%.

**Keywords:** Direct Trips, Distribution System, Tour Trips, Vehicle Routing Problem.

## 1. INTRODUCTION

The central market of Caringin is one of the central markets in the city of Bandung that supplies a variety of commodities to traditional markets spread across the city, including rice. There are 27 traditional markets spread across the city of Bandung. The central market of Caringin and traditional markets in the city of Bandung are managed by Regional-owned Enterprise/Badan Usaha Milik Daerah (BUMD) of Bandung, namely PD Pasar Bermartabat. The location of the central market of Caringin is on Jl. Soekarno Hatta No. 20 Babakan Ciparay, Bandung City, West Java. The location of the central market of Caringin and traditional markets in the city of Bandung can be seen in Figure 1.



**Figure 1** Location of central market of Caringin and traditional markets in Bandung

The existing transportation system used by the central market of Caringin to deliver rice to the traditional markets consists of direct trips. The use of direct trips transportation system causes high transportation costs. Based on a study conducted by [1], the difference between the transportation cost of direct trips and tour trips can reach 19.5%, so there is a need to design a transportation system consisting of tour trips to reduce the transportation cost in the central market of Caringin. The objective of this study is to design tour trips in the central market of Caringin of Bandung that have never been designed before.

According to [2], there are two types of delivery, namely direct trips and tour trips. Direct trips are when one vehicle only serves one customer and then returns to the depot. Tour trips are when a vehicle serves many customers in one trip (tour) and then returns to the depot. These tour trips are then known as a vehicle routing problem (VRP).

## 2. LITERATURE REVIEW

VRP is related to determining the optimal set of routes to be carried out by a fleet of vehicles to serve certain sets of customers. VRP is one of the most important and most studied combinatorial optimization problems. The distribution of goods involves service,

over a period of time, from a set of customers by a set of vehicles, which are located in one or more depots, are operated by a set of crews (drivers), and make movements using appropriate road networks. Specifically, the VRP solution is related to determining a series of routes, each carried out by one vehicle that starts and ends at each depot, so that all customer demands are met, all operational constraints are met, and the global transportation cost is minimized [3].

The road networks, which are used for transporting goods, are generally drawn as graphs, in which arcs represent parts of the roads and the vertices correspond to intersections to depot and customer locations. The arc can be directed or not directed, depending on whether the arc can be traversed only in one direction (for example, due to a one-way street, a typical urban network or toll road) or both directions. Each arc is associated with a fare, which generally represents its length, and travel time, which may depend on the type of vehicle or on the period during which the arc is crossed [3].

There are several previous studies that applied VRP. [4] applied VRP to transport of waste in urban areas. The solution method in [4] was a heuristic method, namely nearest neighbor algorithm. There was also study by [5] that applied VRP to waste collection and transport of trucks in Bandung. The solution method used by [5] was a heuristic method using sequential insertion algorithms. [6] applied VRP to the distribution system of LPG gas. Similar to [4] and [5], [6] also used a heuristic method to solve VRP, namely Palgunadi algorithm. [7] applied VRP to school buses in the city of Bandung. The method used by [7] was a heuristic method, namely travel record-to-record algorithm.

### 3. RESEARCH METHODOLOGY

This study applies VRP to the distribution system of rice in the city of Bandung. The method used is the optimal method by formulating the problem as an ILP (integer linear programming) model of VRP. LINGO 12.0 is used to find the optimal solution.

This study uses [8] as a reference for the ILP model to determine the vehicle routes from the central market of Caringin to the traditional markets in Bandung. [8] developed a model for integrating location, inventory, and route decisions. This study only uses the vehicle route model from [8] as a reference for formulating the ILP model. [8] is used as the reference for this paper because it gave a complete model of ILP for VRP. The formulation is as follows:

#### 3.1. Sets

- $K$  set of traditional markets
- $V$  set of vehicles
- $M$  merged set of traditional markets and central market of Caringin

#### 3.2. Indices

- $k$  index of traditional markets
- $v$  index of vehicles

#### 3.3. Parameters

- $d_{kl}$  transportation cost between node  $k$  dan node  $l$  (Rp) ( $\forall k, l \in M$ )
- $vc$  vehicle capacity (sack)
- $\mu_k$  demand of traditional markets  $k$  (sack) ( $k \in K$ )
- $B$  number of traditional markets contained in set  $K$ , i.e  $B = |K|$
- $OT$  total transportation cost (Rp)

#### 3.4. Decision Variables

- $R_{klv} \{1 \text{ if } k \text{ precedes } l \text{ in route of vehicle } v \text{ 0 otherwise}$   
( $\forall k, l \in M, \forall v \in V$ )
- $M_{kv}$  auxiliary variable defined for traditional markets  $k$  for subtour elimination in route of vehicle  $v$  ( $\forall k \in K, \forall v \in V$ )

#### 3.5. The ILP Model

$$OT = \sum_{v \in V} \sum_{k \in M} \sum_{l \in M} d_{kl} R_{klv} \tag{1}$$

Subject to:

$$\sum_{v \in V} \sum_{l \in M} R_{klv} = 1, \forall k \in K \tag{2}$$

$$\sum_{l \in K} \sum_{k \in M} \mu_l R_{klv} \leq vc, \forall v \in V \tag{3}$$

$$M_{kv} - M_{lv} + (B \times R_{klv}) \leq B - 1, \forall k, l \in K, \forall v \in V$$

$$\sum_{l \in M} R_{klv} - \sum_{l \in M} R_{lkv} = 0, \tag{4}$$

$$\forall k \in M, \forall v \in V$$

$$R_{klv} \in \{0,1\}, \forall k, l \in M, \forall v \in V$$

$$M_{kv} \geq 0, \forall k \in K, \forall v \in V$$

Equation (1) is the objective function which is the total transportation cost. Constraints (2) guarantee that each traditional market is served by a vehicle exactly once. Constraints (3) guarantee that the goods delivered in a vehicle do not exceed its capacity. Constraints (4) are the subtour elimination constraints. Constraints (5) are the constraints of flow conservation: when a vehicle enters a traditional market, the vehicle must leave the same traditional markets and remain circular. Constraints (6)-(7) are the constraints for decision variables.

### 4. RESULTS

As mentioned previously, the solution method used in this study is the optimal method using LINGO 12.0. The ILP model runs on an Intel Core i7 8.00 GB (2.5 GHz) processor.

**Table 1.** Demand of traditional markets

Node	Name of traditional markets	Demand (Sack)
1	Central market of Caringin	-
2	Andir	150
3	Ciroyom	150
4	Anyar	107
5	Pagarsih	107
6	Cijerah	150
7	Dummy	150
8	Dummy	150
9	Cihapit	49
10	Gempol	49
11	Sukahaji	57
12	Leuwipanjang	150
13	Dummy	115
14	Cihaurgeulis	150
15	Dummy	70
16	Cikaso	150
17	Dummy	150
18	Dummy	34
19	Pamoyanan	146
20	Jatayu	146
21	Sadang Serang	150
22	Dummy	54
23	Tilil	150
24	Dummy	54
25	Cicadas	136
26	Kiaracandong	136
27	Cicaheum	136
28	Palasari	150
29	Dummy	70
30	Ciwastra	150
31	Dummy	88
32	Karapitan	126
33	Kota Kembang	126
34	Sederhana	150
35	Dummy	150
36	Dummy	35
37	Gegerkalong	127
38	Sarijadi	127
39	Kosambi	57
40	Ujungberung	150
41	Dummy	88
Total	4.640	

**4.1. Data**

**4.1.1. Demand of Traditional Markets**

Demand of traditional markets is obtained from the multiplication of population per district with consumption per capita. Points of demand are the traditional markets, so the demand is then reduced by the market share of the modern market, which is 40%. The demand is then distributed equally to each traditional market in the district. For the districts that do not have traditional markets, the demand is diverted to traditional markets in the nearest district. If there is a demand for a traditional market that exceeds the capacity of the vehicle, a dummy point is created. The

capacity of the vehicle is 150 sacks. Demand for each traditional market can be seen in Table 1.

**4.1.2. Transportation Costs**

Transportation costs are derived from multiplication of freight rate based on [9], which is USD 0.34/km, with distance between nodes/traditional markets in km. The exchange rate used is Rp 14,385 per dollar. The distance between traditional markets is obtained from Google Maps.

**4.2. Results of The Vehicle Routes**

Table 2 shows the vehicle routes solution from the central market of Caringin to the traditional markets in Bandung. The solution results in a total transportation cost of Rp33,988,890.

An illustration of one of the vehicle route solutions is given in Figure 2. It can be seen that vehicle number 1 has a route that passes through 2 traditional markets, namely Pagarsih Market (5) and Simple Market (36).

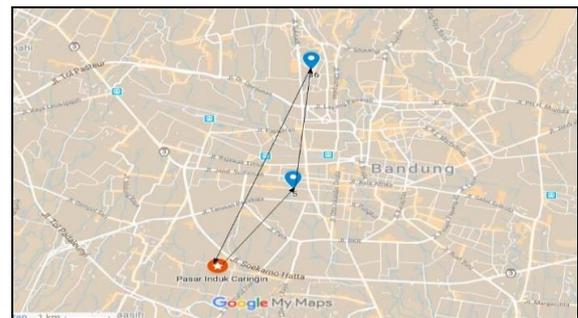
**5. DISCUSSION**

Table 3 provides the direct trips solution currently used to deliver rice from the central market of Caringin to the traditional markets in Bandung. It can be seen in Table 3 that by using direct trips, the number of routes produced is equal to the number of demand points served which is 40 demand points. Likewise, the vehicles used are equal to demand points that are 40 vehicles.

**5.1. The Comparison Between Direct Trips and Tour Trips**

The total distance travelled by the vehicles using direct trips is 627.6 km. In Table 4 and Table 5, it can be seen that tour trips can reduce that distance by 14.03% or 88.05 km. The number of vehicles used is also reduced by 7 vehicles.

In term of the total transportation costs, tour trips result a more efficient cost. By using vehicle rental fee



**Figure 2** The routes of vehicle number 1

**Table 2.** Solution of vehicle routes (tour trips)

Vehicle number	Vehicle route	Total distance traveled (km)	Number of rice delivered (sack)
1	1→5→36→1	16.9	142
2	1→13→1	5.6	115
3	1→18→9→1 0→1	21	132
4	1→14→1	19.6	150
5	1→8→1	7.6	150
6	1→19→1	12.8	146
7	1→24→15→ 1	19.65	124
8	1→25→1	18	136
9	1→40→1	32.2	150
10	1→37→1	22.6	127
11	1→27→1	22.2	136
12	1→38→1	22.6	127
13	1→6→1	7.6	150
14	1→26→1	22	136
15	1→12→1	5.6	150
17	1→35→1	16.8	150
18	1→23→1	19	150
19	1→30→1	20.2	150
20	1→21→1	21.4	150
21	1→20→1	10.2	146
22	1→31→11→ 1	24.3	145
23	1→33→1	11.4	126
24	1→4→1	8.4	107
25	1→17→1	18.4	150
26	1→32→1	9.4	126
27	1→16→1	18.4	150
28	1→2→1	9.6	150
29	1→34→1	16.8	150
30	1→3→1	8.8	150
31	1→39→29→ 1	14.4	127
32	1→28→1	12	150
33	1→7→1	7.6	150
34	1→41→22→ 1	36.5	142
Total	539.55	4,640	

in Bandung, which is Rp 950,000/vehicle, the total transportation cost of tour trips is Rp33,988,890. It results an efficiency of 17.24% comparing to the total transportation cost of direct trips which is Rp41,069,529.

**6. CONCLUSIONS**

This study has successfully applied VRP to the rice distribution system in Bandung. The method used is the optimal method by formulating the problem as an ILP model of VRP. LINGO 12.0 is used to find the optimal

**Table 3.** Solution of direct trips

Vehicle number	Direct trips	Total distance traveled (km)
1	1→2→1	9.6
2	1→3→1	8.8
3	1→4→1	8.4
4	1→5→1	8.6
5	1→6→1	7.6
6	1→7→1	7.6
7	1→8→1	7.6
8	1→9→1	16.4
9	1→10→1	17
10	1→11→1	6.4
11	1→12→1	5.6
12	1→13→1	5.6
13	1→14→1	19.6
14	1→15→1	19.6
15	1→16→1	18.4
16	1→17→1	18.4
17	1→18→1	18.4
18	1→19→1	12.8
19	1→20→1	10.2
20	1→21→1	21.4
21	1→22→1	21.4
22	1→23→1	19
23	1→24→1	19
24	1→25→1	18
25	1→26→1	22
26	1→27→1	22.2
27	1→28→1	12
28	1→29→1	12
29	1→30→1	20.2
30	1→31→1	20.2
31	1→32→1	9.4
32	1→33→1	11.4
33	1→34→1	16.8
34	1→35→1	16.8
35	1→36→1	16.8
36	1→37→1	22.6
37	1→38→1	22.6
38	1→39→1	12.8
39	1→40→1	32.2
40	1→41→1	32.2
Total	627.6	

**Table 4.** The comparison between direct trips and tour trips (part 1)

Transportation system	Total distance travelled (km)	Number of vehicles (vehicle)
Direct trips	627.6	40
Tour trips	539.55	33
The difference	88.05	7

**Table 5.** The comparison between direct trips and tour trips (part 2)

Transportation system	Total transportation cost	Efficiency
Direct trips	Rp41,069,529	17.24%
Tour trips	Rp33,988,890	
The difference	Rp7,080,639	

solution. The cost efficiency obtained by applying VRP in this study is 17.24%. The status of the solution in this study is a feasible solution and the computational time takes 167 hours 52 minutes 38 seconds. These are due to the large amount of data used which are 40 demand points. ILP belongs to the NP-hard problem. This causes the computing time to get longer as the amount of data used increases. For further work, it is needed to develop heuristic methods to produce better quality solutions with reasonable computing time.

## ACKNOWLEDGMENTS

Authors would like to thank the Ministry of Research and Technology/National Agency for Research and Innovation of Indonesia for the Grant of Penelitian Dosen Pemula (PDP) 2020 (Number: 012/SP4/LP2M-UTAMA/VI/2020).

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