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A Mathematical Model for Solving Distribution System Problem by Considering Odd-Even Vehicle License Plate Rule

Andika Dwi Nugraha[1*], Winarno[1], Aulia Fashanah Hadining[1]

Abstract: This research discusses the goods distribution system in an urban area by considering an odd-even vehicle license plate rule. This rule enables the vehicles with the even-number plate to pass particular roads on even-number dates and vice versa during specific time intervals determined by the authority. This rule is potentially rising the company's logistic cost up to 20%. Therefore, a Mixed-Integer Linear Programming model is developed to solve the problem. The performance of the model is tested on some numerical examples. Computational results show that the model generates optimal solutions with numerous computational times. The instances of customers located randomly and clustered manner (i.e., mix) are arduous to solve. The average computational time of these instances is 1 hour and 35 minutes.

Keywords: Odd-even vehicle licence plate rule, vehicle routing problem, road operational hour, mixed-integer linear programming.

Introduction

Logistics activity is an important activity in supply chain management besides sourcing and manufacturing activities [1]. In practice, logistic activities are related to storing and distributing goods, raw materials, parts, and final products. All of these activities need to be managed properly so that the logistics costs incurred become more efficient. Shen and Lian [2] revealed that the logistics cost components include facility location cost, transportation cost, inventory cost, and ordering cost. Transportation costs contributes 56% to the logistics costs [2].

According to Rodrigue *et al.* [3], distance is one of several factors that linearly influence the cost of transportation. The transportation cost is due to fuel consumption, which directly affects the distance traveled by the vehicle during the goods distribution process. Therefore, poor distribution route planning could cause high transportation costs [3]. In distribution management, the problem related to optimal route planning is known as the Vehicle Routing Problem (VRP) [4]. Solving the VRP resulted in the global transportation cost can save about 5% – 20% [5].

One of the specific VRP families is the Vehicle Routing Problem with Time Windows (VRPTW). VRPTW determines the distribution route by considering the operational time windows at the depot and customer locations [6]. An example of VRPTW can be found in fuel oil distribution, where each customer has the opening and closing time [7]. Moreover, the development of node time-constrained problems incorporating multiple trips and pickup delivery has been presented by Suprayogi and Priyandari [8] in response to a case of the pickup and delivery of Liquified Petroleum Gas (LPG) tubes. In several cases, the operational time windows are limited to all specific nodes, but the road connection between two nodes also has the operational time interval. The road operational time interval can be found in the city transportation system, where trucks cannot enter roads in the city at certain hours when the traffic density level is high [9,10].

In Indonesia, a similar problem can be found in the traffic restriction policies using the Odd and Even vehicle license plate rules in DKI Jakarta. This policy has been enforced based on the Regulation of the Governor of DKI Jakarta Number 88 of 2019 to solve traffic congestion problems in Jakarta. This policy has two provisions in which every four or more wheeled vehicle with an odd plate number is prohibited to traverse predetermined road sections which have been assigned on the even date. In contrast, even licence plate vehicles are not allowed to cross on the odd date. These conditions are stipulated during the operating hours, ranging from 06.00 - 10.00 and 16.00 - 21.00 Western Indonesian Time (WIT). Implementing the traffic restriction policy severely impacts the logistics company due to its vehicle fleets being restricted by the policy. Thus, it can hinder its logistics activities in the Jakarta area. Several companies have attempted to seek compensation from the local

[1]Faculty of Technology, Department of Industrial Engineering, Universitas Singaperbangsa Karawang, Jl. H.S. Ronggowaluyo, Teluk Jambe Timur, Karawang, Indonesia 41361. Email: andikadwinugraha8@gmail.com, winarno@staff.unsika.ac.id, aulia.fasha@staff.unsika.ac.id

* Corresponding author

Table 1. State of the art

Year	Author	Problem characteristics				Objective Function (minimization)
		Multi-echelon	Multi-depot	Time windows		
				On-location	Connecting road	
2013	Çetinkaya *et al.* [9]	☑			☑	Variable cost (transportation cost)
2016	Bae *et al.*[13]		☑	☑		Fixed cost (depot and vehicle cost) and variable cost(transportation and labor cost)
2020	Zhen *et al.*[14]		☑	☑		Cost based transportation time and vehicle allocation
2020	This research		☑		☑	Variable cost (transportation cost)

government of DKI Jakarta for the consequences of this policy [11]. However, these efforts have yet to produce results.

The impacts are as follows. On the odd date, vehicles with an even license plate number cannot operate in the road section, which is included in the restriction area during a predetermined time interval. Even though the vehicles can operate, the company still struggles to distribute goods because it has not maximized its entire vehicle fleet. The same rule is applied to vehicles with odd plate numbers operating on even dates. Thus, to overcome this circumstance, several companies, such as courier service companies, allocate a portion of the goods delivery by increasing the number of motorbike fleets free from this policy. However, the strategy potentially increases the logistics cost by up to 20% [12]. Therefore, the companies need to design the optimal goods distribution route on the entire available vehicle fleets but still adhere to the government's traffic restriction policy.

In line with the description above, this study proposes a Mixed-Integer Linear Programming (MILP) model to solve the Distribution System Problem Considering Odd or Even-number Vehicle Rule (DSPCOEVR). The objective function of the model is to minimize the variable transportation costs during the goods distribution process. This model is tested on several numerical examples to ensure that the proposed mathematical model can be implemented for similar cases.

The extension of time windows restriction can be found in the study discussed by Bae *et al.* [13]. The case study was the process of delivering and installing electronic products. The authors proposed a MILP model and a Genetic Algorithm method to solve the problem. Meanwhile, Zhen *et al.* [14] presented the MILP model along with the Hybrid Particle Swarm Optimization (HPSO) algorithm and the Hybrid Genetic Algorithm (HGA) in solving VRPTW with multiple depots, multiple trips, and the release date of the goods delivery. Both [13] and [14] dealt with time window restrictions at the depot and customer locations. The limitation of road operating time was first discussed by Çetinkaya *et al.* [9]. A mathematical model and Memetic algorithm were proposed in this research and produced a reasonably good solution with a relatively short computational time. Çetinkaya *et al.* [9] continued the study about developing a mathematical model that is used to solve the problems in selecting the location of distribution facilities (i.e., Location Routing Problem) [10]. The mathematical model is an extension of the VRP model by considering the aspects of determining the depot location. Both studies took case studies on the military logistics system in Turkey. Table 1 summarizes the comparison of this research with related studies. In the previous study discussed by Çetinkaya *et al.* [9], the vehicle departure time from the original location is less than or equal to the operational end time of a road, enabling the vehicle arrival time at the destination point exceeds the time limit of using the road. This study is addressed in the model development section.

This paper is organized into several sections as follows. The definition of the problem, along with the mathematical model, is shown in the Methods section. Meanwhile, the computational results from model testing are discussed in the Results and Discussion section. Finally, the conclusions and future recommendations are presented in the last section.

Methods

Problem Framework

DSPCOEVR is a problem of the vehicle route determination problem to distribute particular demands of either direct customers or retailers by considering road time limit in line with the even-odd vehicle plate number rule. This rule is one of the government's attempts to restrict the vehicle volume that passes across several congestion points. Some vehicles can pass through the road in segmented time

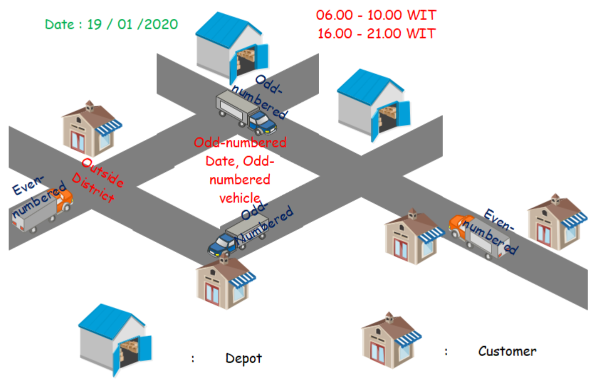

Figure 1. Odd-Even vehivle license plate rule illustration.

based on their vehicle license plate number, whether it has an even or odd number associated with the date of the rule enforcement. For instance, if the enforcement date falls in even number, only the even-number plate vehicles can operate in a particular road during specific time intervals and vice versa. However, it noted that not all the roads are tied under this rule. The restricted vehicles are only prohibited from traversing the predetermined road, which means those vehicles are permitted to access several roads outside the odd-even location.

This rule is enforced hourly from 06.00 – 10.00 WIT and 16.00 – 21.00 'WIT throughout the day. Thus, on the interval time start from 10.00 – 16.00 WIT and 21.00 – 06.00 WIT, the restricted vehicles are permitted to traverse the "prohibited" road. This rule is implemented for five days each week. Figure 1 illustrates the implementation of the rule. A policy regarding traffic restriction rules considering odd and even license plate force companies to look for alternative routes so that the goods delivery can reach the customer's location at the minimum cost. The vehicle must concern the road sections included in the traffic restriction area and the operational time windows to achieve the desired objective function. Besides, each vehicle has the amount of load containing several customer requests for each route and gradually decreases as each customer demand is fulfilled. Therefore, the assumptions and scopes of the proposed model are as follows: (1) The number of depots used is more than one. (2) Each route begins and ends at the same depot. (3) One vehicle is only used for a maximum of one route. (4) Each customer is only visited by one vehicle exactly once. (5) Each route to be traversed by a vehicle has a predetermined operational time window. A vehicle is prohibited from traveling a particular road outside its operational timeframe and must wait until the road operating time starts. (6) The total vehicle load of the route must not exceed the capacity of the vehicle. (7) The transportation cost only comes from the cost of fuel consumption per unit distance.

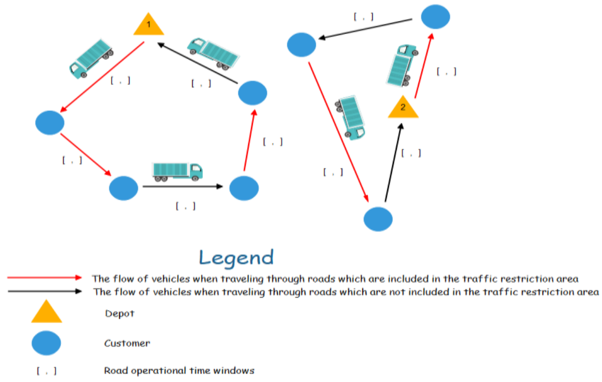

Figure 2. Illustration of goods distribution network

In addition, the proposed model focuses only on how the vehicle can cope with the time limit that exists for taking each path option. Therefore, this study only concentrates on one type of vehicle under constraint, i.e., odd-number or even-number license plate.

Mathematical Model

DSPCOEVR can be defined as a graph $G = (N, R)$ shown in Figure 2. Let N be the set of all location points, and $R = \{(i,j)|i \neq j, \forall i,j \in N\}$ be the set of all connecting roads. N consists of $D = \{1, \ldots, n\}$ and $C = \{n+1, \ldots, n+w\}$ which are the set of all available depots and customers. n and w are positive integer numbers which represent number of depots and customers, respectively. Each vehicle has the amount of capacity Q to serve each customer's demand q_i $(i \in C)$, in which $q_i \leq Q$.

To fulfill each customer's demand, each vehicle must traverse across the roads which has the predetermined operational time interval $[a_{ij}, b_{ij}]$ where $i \neq j$. Moreover, the vehicle trip between location has a variable cost c_{ij} that is influenced by the non-negative distance traveled ds_{ij} and vehicle travel time T_{ij}.

The model is developed using Mixed-Integer Linear Programming (MILP) to minimize vehicle transportation cost, which is a variable cost that depends on the distance traveled by the vehicle during the distribution process. The developed mathematical model produces output in (1) The vehicle route to distribute goods to each customer. (2) The departure time from each customer after the service. (3) The amount of load on the vehicle right before serving the customer. (4) A list of customers assigned to each depot.

This mathematical model does not consider operational time windows on each customer and depot, the length of time for vehicle service to each customer, the congestion during the trip, and routing for both types of vehicles (i.e., vehicles with odd and even license plates) simultaneously.

The notation for the set, the parameters, and the decision variables used in this mathematical model is given as follows.

Sets

N : Set of all location points
D : Set of all depot points
C : Set of all customer points

Parameters

Q : Vehicle capacity
q_i : Demand of customer i ($\forall i \in C$)
c_{ij} :Transportation cost between two nodes ($\forall i, j \in N$)
FC : Vehicle fuel cost
ds_{ij} : Distance between two nodes ($\forall i, j \in N$)
T_{ij} : Vehicle travel time when traveling through road ($\forall i, j \in N$)
a_{ij} : Earliest available time of a road ($\forall i, j \in N$)
b_{ij} : Latest available time of a road ($\forall i, j \in N$)

Decision Variables

x_{ij} = 1 if the vehicle goes directly from point i to point j; 0 otherwise, ($\forall i, j \in N$)
d_i : Departure time of a vehicle from customer i ($\forall i \in C$)
u_i : The amount of load on the vehicle right before serving customer i ($\forall i \in C$)
y_{ih} = 1 if customer i is assigned to depot h; 0 otherwise ($\forall i \in C, \forall h \in D$)

The objective function and constraints are formulated as follows.

Objective Function

Equation (1) aims to minimize variable transportation cost. The amount of this cost is proportional to the distance traveled by the vehicle during the distribution process

$$Min\ \sum_{i\in N}\sum_{j\in N} c_{ij}x_{ij} \tag{1}$$

Vehicle Flow

Equation (2) ensures that each assigned vehicle visits each customer once. Meanwhile equation (3) ensures that every vehicle visits the customer, then leaves it, either to the next customer or the final destination.

$$\sum_{i\in N} x_{ij} = 1 \qquad \forall j \in C \tag{2}$$
$$\sum_{j\in N} x_{ji} - \sum_{j\in N} x_{ij} = 0 \qquad \forall i \in N \tag{3}$$

Subtour Elimination and Vehicle Capacity Restriction

Equation (4) assures route connectivity subject to vehicle capacity. Equations (5) and (6) determine the upper and lower bound of the amount of load carried by a vehicle. Equations (4) - (6) are the constraints to eliminate the sub tour.

$$u_j - u_i + Qx_{ij} + (Q - q_i - q_j)x_{ji} \le Q - q_i \quad \forall i, j \in C\ ; i \ne j \tag{4}$$
$$u_i \ge q_i + \sum_{j\in C, j\ne i} q_j x_{ij} \qquad \forall i \in C \tag{5}$$
$$u_i \le Q - (Q - q_i)\sum_{h\in D} x_{ih} \qquad \forall i \in C \tag{6}$$

Road Operational Time Restriction

Equation (7) ensures that the departure time of each customer depends on the previous customer. Equations (8) and (9) ensure that the vehicle departure time from each location point to another location starts after the earliest available time of the road. If the earliest operational time of the road has not started, the vehicle must wait until the road is allowed to traverse. Equation (10) indicates that the departure time of the vehicle from each customer point to another location point must not exceed the latest available time of the road. Equation (10) also forces vehicles to arrive at the following location before the road is closed.

$$d_i - d_j + M_{ij}x_{ij} \le M_{ij} - T_{ij} \quad \forall i, j \in C\ ; i \ne j \tag{7}$$
$$d_j \ge (a_{hj} + T_{hj})x_{hj} \quad \forall j \in C, \forall h \in D \tag{8}$$
$$d_i \ge a_{ij}x_{ij} \qquad \forall i \in C\ , \forall j \in N\ ; i \ne j \tag{9}$$
$$d_i \le b_{ij} - T_{ij} + L_{ij}(1 - x_{ij}) \ \forall i \in C\ ; \forall j \in N\ ; i \ne j \tag{10}$$

Constraints (7) dan (10), M_{ij} and L_{ij} are large constants, from which both values are derived as follows:

$$M_{ij} = \alpha_i - \beta_j + T_{ij} \quad \forall i \in N, \forall j \in N\ ; i \ne j \tag{11}$$
$$L_{ij} = \alpha_i - b_{ij} \qquad \forall i \in N, \forall j \in N; i \ne j \tag{12}$$

where

$$\alpha_i = max_{j\in N}(b_{ij} + T_{ij}) \qquad \forall i \in N; i \ne j \tag{13}$$
$$\beta_j = min_{h\in D}(a_{hj} + T_{hj}) \qquad \forall j \in C \tag{14}$$

α_i and β_j are additional parameters to speed up the process of finding the optimal solution [9].

Customer Assignment

Equation (15) ensures that each customer is assigned to at most one depot. Meanwhile, for equations (16) and (17), the distribution process occurs if a specific depot assigns the first and last customer. Vehicles must depart from the origin depot and end at the destination depot. In other words, the starting point of the vehicle route is not the customer. Equation (18) ensures that the trip of a vehicle between 2 customer points occurs if the origin and destination depot are identical. If the origin depot and the destination depot are two different depots, the goods distribution process does not occur. Figure 3 is the illustration in which are the customers are assigned to a specific depot. For instance, customers 1, 3, and 4 are

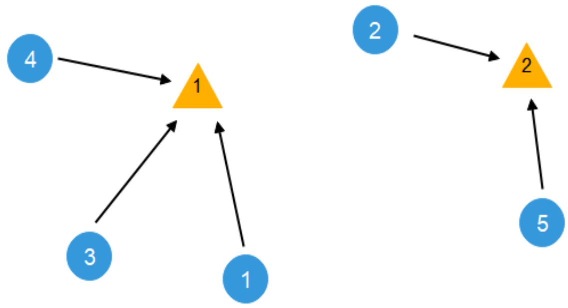

Figure 1. Illustration of customers assignment to depot

assigned to depot 1, while customers 2 and 5 are assigned to depot 2.

$$\sum_{h\in D} y_{ih} = 1 \quad \forall i \in C \tag{15}$$
$$x_{ih} \leq y_{ih} \quad \forall i \in C,\ \forall h \in D \tag{16}$$
$$x_{hi} \leq y_{ih} \quad \forall i \in C\ ,\ \forall h \in D \tag{17}$$
$$x_{ij} + y_{ih} + \sum_{k\in D, k\neq h} y_{jk} \leq 2 \quad \forall i,j \in C, i \neq j, \forall h \in D \tag{18}$$

Non-negativity and Integrality

Variable (19) and (21) are expressed in the form of binary integer. Meanwhile, variables (20) are nonnegative.

$$x_{ij} \in \{0,1\} \quad \forall i,j \in N \tag{19}$$
$$u_j, d_j \geq 0\ \forall j \in C \tag{20}$$
$$y_{ih} \in \{0,1\} \quad \forall i \in C, \quad \forall h \in D \tag{21}$$

Minimum Number of Routes

Equation (22) is a valid inequality to determine the minimum number of routes originating from the certain depot.

$$\sum_{j\in C} x_{hj} \geq \sum_{i\in C} {}^{q_i}/_{Q}\ , \quad \forall h \in D \tag{22}$$

Transportation Cost

Equation (23) attempts to find transportation costs, which ds_{ij} is the distance traveled by a vehicle from the origin point to the destination point. Meanwhile, *FC* represents the cost of vehicle fuel per unit distance

$$c_{ij} = ds_{ij} \times FC \quad \forall i,j \in N \tag{23}$$

Results and Discussions

The developed mathematical model is written using the AMPL programming language (A Mathematical Programming Language) and solved using the Gurobi solver version 9.0.2. The entire process for running this model is carried out using the AMD A8-7410 APU with AMD Radeon R5 Graphics 2.20 GHz, 4 GB, and Windows 10 OS. Several tests were conducted to understand the performance of this mathematical model. The computational experiment consisted of 2 parts. First, the classical Solomon benchmark instances are used. This test aims to determine the total transportation costs spent on each characteristic of the customer location using converted road time windows. Then, the second test uses numerical data that has been generated by considering the predetermined time interval of the traffic restriction rules with the odd and even system along with the roads that have been stipulated in the DKI Jakarta Governor Regulation Number 88 of 2019. This second test aims to determine whether the mathematical model used developed can be implemented on DSPCOEVR or not. In both tests, additional data is included, such as the transportation cost and constant vehicle speed, which are Rp. 600 / km and 60 km/hour, respectively.

First Test Computational Results

For the first test, the VRPTW classical benchmark instances were chosen [15]. This dataset consists of several problem types, which are categorized based on the distribution of customer locations and the characteristics of the time windows width. The characteristics of the customer location consist of 3 categories, namely type R, C, and RC. Type R is a numeric data type where the location of each customer is scattered randomly (random), while in type C, the location of each customer is scattered in a cluster way. Meanwhile, for the RC type, the location of each customer is scattered both in a cluster and random manner (mix). Based on the characteristics of the road operational time windows, this numerical data is divided into two groups, namely the short (tight) and long (wide) operational time ranges. In the short operational time windows, the vehicle capacity is 200 units in R1, C1, and RC1, making it possible for one vehicle only to visit a few customers. Meanwhile, in the long operational time windows, the maximum vehicle load is 1000 units for the R2 type, 700 units for the C2 type, and 1000 units for the RC2 type, making it possible for one vehicle to visit many customers. These tests involve 25 customers along with two depots.

Since there is no road operational time in Solomon instances, a particular procedure is presented to convert the node operational time provided in the dataset to the road operational time as follows:

The operational start time is obtained based on the smallest value of the starting time of operation between 2 location points connected by the road. For example, to determine the starting time of road operations from node 2 to node 4, node 2 has an open time of 450 minutes while node 4 has an open time of 300 minutes. As a result, the operational time of the

Table 1. Computational results for the first test

Sample	Total distance (Kilometer)	Total cost (Rupiah)	Sample	Total distance (Kilometer)	Total cost (Rupiah)
C101 25	269.21	161,529	R201 25	340.18	204,108
C102 25	267.57	160,543	R202 25	331.63	198,978
C103 25	265.76	159,456	R203 25	315.72	189,431
C201 25	216.08	129,647	RC102 25	612.38	367,428
C202 25	202.99	121,792	RC103 25	611.93	367,156
C203 25	202.65	121,591	RC104 25	611.93	367,156
R101 25	420.13	252,076	RC202 25	299.68	179,808
R102 25	361.46	216,878	RC203 25	299.68	179,808
R103 25	348.38	209,026	RC204 25	299.68	179,808

road connecting node 2 to node four is started in the 300th minute.

The end time of a road operation is obtained based on the greatest value of the end of operation time between 2 location points connected by the road. For example, to find the end time of the road operation from node 2 to node 4, node 2 has a closing time of 900 minutes while node 4 has a closing time of 650 minutes. As a result, the operational time of the road connecting node 2 to node four is ending in the 900th minute.

These numerical data assume that the distances connecting between locations are Euclidean distances.

Based on the computation results shown in Table 1, the average value of total transportation costs for categories C2, R2, and RC2 is cheaper than categories C1, R1, and RC1. In other words, the long road time windows category generates less total transportation cost than the short road time windows category (see belowFigure 2).

The clustered type has the minimum average total transportation cost compared to the random and mixed types in terms of the customer location distribution. The comparison of the transportation costs of each type of customer location is presented in Figure 5.

To measure how difficult the model's completion is for each characteristic, the calculation of the computation time in detail can be seen in Table 3. The categories of customers scattered in a cluster manner with the characteristics of the tight time windows are more challenging to solve than the wide time windows. For the type of randomly distributed customer locations, the model computation time for tight and wide time windows does not significantly differ.

Meanwhile, for the mixed distribution of customers problem sets, the wide time windows (RC2) characteristics are challenging to solve compared to the tight time windows (RC1). RC2 category requires 1 hour 35 minutes to be solved. Overall, the mixed

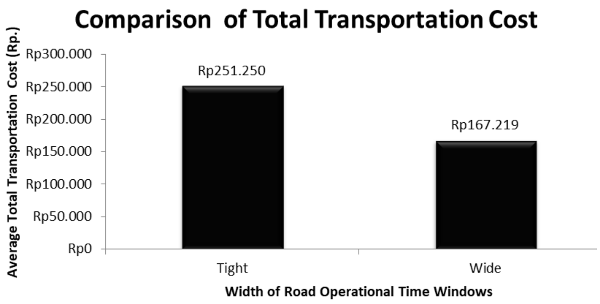

Figure 2. Comparison based on time windows characteristics

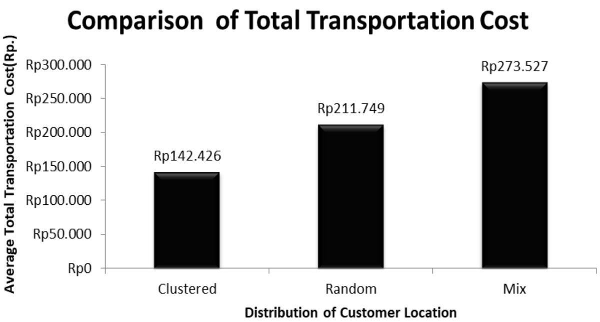

Figure 3. Comparison based on distribution of customer location

distribution of customers is more challenging to solve than the random and cluster categories.

Second Test Computational Results

In the second test, several numerical samples on a small scale were generated using artificial data, which was used as a representation of the DSPCOEVR in DKI Jakarta. This dataset is generated to determine whether this mathematical model can be applied to solve DSPCOEVR or not. In this numerical example, 30 customer locations (symbolized as stars) around DKI Jakarta were randomly selected with two distribution centers as depots (symbolized as squares), as shown in Figure 6. In addition, this numerical example considers several roads (symbolized as a flag) along with the timeframe specified in the traffic restriction with the odd and even vehicle number rules. This numeric example is divided into two categories, namely 15 customer categories and 30 customer categories. In the 15

Table 2. Computational time for each sample

Sample	Computational time (s)	Average computational time(s)
C101 25	156,84	506,78
C102 25	419,23	
C103 25	944,27	
C201 25	621,38	241,15
C202 25	64,20	
C203 25	37,88	
R101 25	36,89	15,77
R102 25	6,50	
R103 25	3,91	
R201 25	40,51	18,54
R202 25	13,70	
R203 25	1,41	
RC102 25	3,03	2,32
RC103 25	2,19	
RC104 25	1,75	
RC202 25	4302,73	5713,69
RC203 25	8218,55	
RC204 25	4619,80	

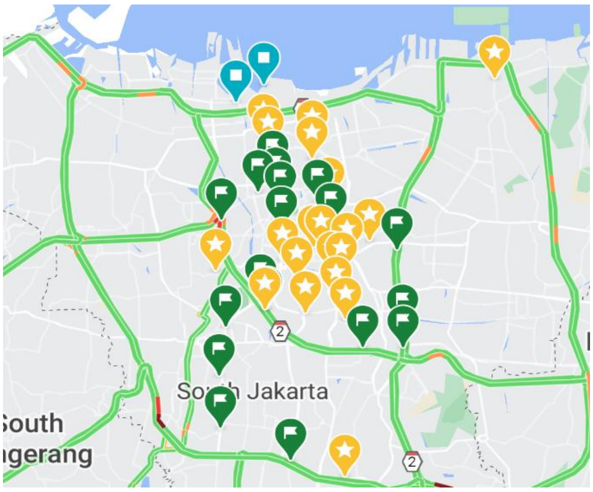

Figure 4. Illustration of selected location points and road sections for the second test

customer categories, all retailers are located in the odd and even traffic restriction areas. Meanwhile, for the 30-customer category, some customers are located in the odd and even traffic restriction areas, some are outside the odd and even traffic restriction areas. For category 15 customers, the vehicle departs at 10.00 WIT - 16.00 WIT shortly after session 1 of the odd and even traffic restriction ends. As for the 30-customer category, some customers who are outside the odd and even traffic restriction areas are scheduled to be visited within the time range of 06.00 WIT - 21.00 WIT. The distance value along with the estimated travel time is based on the Google Maps application.

In these tests, each customer's demand is assumed to be deterministic, homogen and generated as random integer number which ranges from 10 to 80 units. Also, the amount of vehicle capacities are 200, 250 and 300 units.

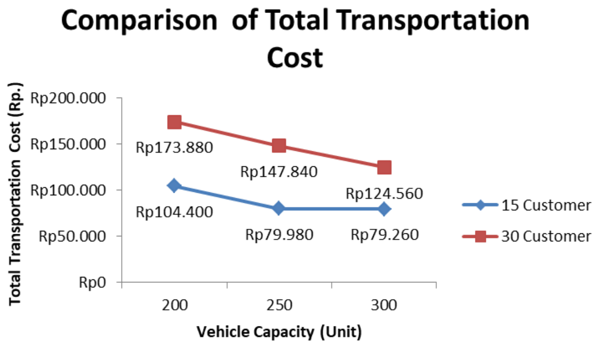

Figure 5. Total transportation cost comparison

Figure 7 exhibits the total transportation costs of each numerical sample category. The sample DSPCOEVR 15 (200 units) indicates that the sample is included in the category of 15 customers with a vehicle capacity of 200 units. In comparison, DSPCOEVR 30 (200 units) implies that the sample belongs to the category of 30 customers. In the 15-customer category, an increase in vehicle transport capacity from 200 to 300 units decreased total transportation costs by 24.08%. In comparison, the 30 customer categories resulted in a decrease in total transportation costs by 28.36%. Then, for category 15 customers, the change in vehicle capacity from 250 to 300 units was not too significant, namely 0.9%, while for 30 customers, it resulted in a decrease in total transportation costs by 15.75%.

In the 15-customer category, each sample does not have a significant difference in turnaround time even though the vehicle capacity has changed. While for the category of 30 customers, there are significant differences in each sample (see Table 4). The most significant difference is when changing the vehicle capacity parameter to 300 units, which takes 3 hours 27 minutes to be solved.

Comparison with Salomon's Model [6]

This section presents the comparison between the result of this proposed model with Solomon's model [6] as shown in Table 5. Total distance values of Solomon's model [6] is significantly different with the proposed model. Since the Solomon's model considers service time in constructing the routes.

Conclusion

This study developed the Mixed-Integer Linear Programming model to solve the distribution system problem considering odd and even license plate vehicles rule (DSPCOEVR) in an urban area. The model aims to optimize the vehicle routes with minimum travel cost and ensures that the related constraints are adequately satisfied. The model can be applied in the various goods distribution system (e.g., consumer goods, spare parts, or packaged goods)

Table 3. Computational time

Sample	Vehicle capacity (units)	Number of customers at odd/even location	Number of routes	Computational time (s)
DSPCOEVR 15 (200)	200	15	8	1,36
DSPCOEVR 15 (250)	250	15	6	1,22
DSPCOEVR 15 (300)	300	15	6	1,73
DSPCOEVR 30 (200)	200	16	12	44,77
DSPCOEVR 30 (250)	250	16	10	555,01
DSPCOEVR 30 (300)	300	16	8	10342,9

Table 4. Comparison between Solomon's model [6] and this research

Sample	Solomon [6] (kilometer)	This research (kilometer)	% Change
C101 25	191.3	269.21	29
C102 25	190.3	267.57	29
C103 25	190.3	265.76	28
C201 25	214.7	216.08	1
C202 25	214.7	202.99	-6
C203 25	214.7	202.65	-6
R101 25	617.1	420.13	-47
R102 25	547.1	361.46	-51
R103 25	454.6	348.38	-30
R201 25	463.3	340.18	-36
R202 25	410.5	331.63	-24
R203 25	391.4	315.72	-24
RC102 25	351.8	612.38	43
RC103 25	332.8	611.93	46
RC104 25	306.6	611.93	50
RC202 25	338.0	299.68	-13
RC203 25	326.9	299.68	-9
RC204 25	299.7	299.68	0

that inherently encounters a road operational time restriction (road time windows). According to the several tests that have been conducted, the model can provide the optimal solution for some characteristics of the customer location distribution (e.g., Random, Cluster, Random-Clustered) and the width of the road time windows (e.g., tight and wide).

However, due to its NP-Hard properties, the larger the size of the problem, the more arduous it to be solved. In other words, the model needs a long time to find the optimal solution. Therefore, future research will be performed by developing a heuristic or metaheuristic method that will be promising to obtain a good quality solution in a reasonable time. Moreover, expanding the assumption of the model constraint is necessary to enhance the model's applicability. Some additional constraints will be incorporated into the model such as the open and close time on each location (i,e, depot and customer), the limitation of the number of vehicles will be used, the utilization of both types vehicles (i.e. odd-number and even-number plate) simultaneously, and considers multiple road operational time interval.

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