Optimization of Location Selection for Electric Motorcycle Charging Station: Distance-based Method Approach

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Abstract

The mass adoption of electric mobility will reflect advances in the vehicle itself, its infrastructure network, and its position in the automotive market. Progress in these areas is highly related, and mandates coordinated design efforts. Discuss ongoing developments and future trends in charging systems for E-Motorcycle vehicles. E-Motorcycle can grow rapidly if supported by facilities in certain areas that can be used to exchange batteries or recharge batteries because the batteries used have the maximum capacity so that electric vehicles also have limited mileage. This research uses a supply chain network model to determine charging station facilities in Semarang city to achieve coverage from the fewest number of charging stations and minimum investment costs. The method used in determining location distance uses a distance-based by solving problems built from combinations and modifications of models in previous studies, and models run using CPLEX. From the results of operations using ILOG CPLEX, it was found that the optimal results of charging station locations are 4 location points (E2, J1, N3, and O2) with each districts having one charging station that can provide recommendations and input to the Semarang City Government in the problem of providing charging stations.

Keywords:
Charging Station, Distance-based Method, E-Motorcycle, Location Facility, Supply Chain Network Design

1. Introduction

The producer of air pollution in the motorized vehicle sector is due to the very fast growth which reaches a value of 30% as a big problem from an environmental aspect (Ismiyati *et. al.,* 2014; Habibie and Sutopo, 2020). Therefore the government accelerates the process of procuring E-Motorcycle battery vehicles to increase energy efficiency, as well as to reduce air pollution that has already occurred. E-Motorcycle is considered as new transportation to reduce air pollution and encourage environmental sustainability, with a battery-based material to store the energy needed to drive the vehicle (Rong and Max, 2013). One of the drivers to downstream the electric vehicles is the availability of infrastructure, namely the charging station (Sutopo *et. al.,* 2019; Istiqomah and Sutopo, 2020). Then, supply chain network design is needed to determine the location, number, and capacity of production facilities. It aims to meet customer needs which of course can change dynamically from time to time (Klibi, 2010). The supply chain network is the result of several strategic decisions, one of which is a decision about the location of production facilities and decisions about purchasing raw materials (Wahyudin, *et al.*, 2015; Pujawan, 2017).

We elaborated on the previous researches related to Electric Vehicle Charging Station Facilities. Zhang *et. al.* (2017) examined the optimization of the location of electric ship charging stations based on the backup coverage model by analyzing feasibility, reserve location models, and optimization methods. Then Pagany *et. al.* (2019) examined the determination of a charging station for Electric vehicles (EV) using a model of location for electric charging requests. And Akbari et. al (2018) studies several limitations such as the power of charging stations, the average time needed for each recharge, and the distance traveled per day by applying the Genetic Algorithm (GA) to calculate the number of charging stations to be determined. From previous research, the model used in this study is a model with a distance-based approach method. Zhang *et. al.* (2017) so that the reference model used is a distance-based approach which aims to maximize the current coverage of Battery Electric Vehicle (BEV) by placing many charging stations on the road segment by considering cost constraints, which can produce results showing that equilibrium traffic flow is influenced by charging speed, range limit, of the charging facility utility and that the driver, and Fazeli *et. al.* (2020) to maximize the expected access of EV drivers to charging stations and maximize EV traffic flow.

In this study, we used Semarang City, Indonesia as a case study. We assumed The Semarang City Government has to ensure the provision of charging stations in collaboration with Pertamina (SPBU), to ensure optimal coverage of charging stations with feasible distances between points. The means of providing a place for a charging station is at a gas station, but it is necessary to find the optimal location for the charging station to be built at the gas station. The application of charging stations is the most significant problem for the electric vehicle (EV) industry. For this reason, by optimizing the distance between charging stations, costs can be minimized (Akbari et. al., 2018). Gas stations that are scattered throughout the city are potential locations to be chosen as places for making charging stations. Gas stations are seen as one of the effective solutions that have been considered. Gas stations that are scattered in the city are potential locations to be used as charging stations. This study aims to optimize the selection of charging station locations for E-Motorcycle facilities in the city of Semarang. The potential of this facility is used as a location for gas stations, where these facilities are often and easily found by the community. In this study, there are 3 entities involved, namely charging station providers, gas station owners (government or private), users of E-Motorcycle.

2. Methodology

The model in this study is the development of the model in Zhang *et. al.* (2017) and Pagany *et. al.* (2019). From these two studies, a model was made to determine the optimization of the charging station location for E-Motorcycle. This study considers maximizing coverage demand and minimizing costs. Table 1 describes the comparison between the two models.

Table 1. Comparison Of the Two Models

Aspect	Zhang *et. al.* (2017)	Pagany *et. al.* (2019)
Object of research	Electric Boat Charging Station	Charging Station Electrical Vehicle
Method	• Feasibility Analysis • Reserved Location Model and Optimization Method	Model of Electric Charging Request Location (ECDL)
Coercion	• Vessel filing requirements must be met	• One user can only charge at one charging station

	• One class charging station can be built at the candidate site	• Limited service capacity of filling stations
Alternative Solutions	5 filling station locations were selected as candidate filling locations	Propose location models based on electric charging demand as candidate locations in determining the distribution of charging stations and battery exchange
Software Applications	Matlab 7.0	Matlab
Output	The overall location problem, from the possible location of the starting station chosen to the determination of the capacity for the final location	A wide range of electrical energy demand while considering as many destinations as possible within an acceptable walking distance threshold

The network optimization study aims to determine the location for making battery charging within the optimal distance for the needs of E-Motorcycle users. From this project, what must be available is the location of the battery charging station for E-Motorcycle. The location data for the selection of manufacturing locations can be increased and the distance between districts and gas stations, for which problem needs to be fixed is the increase in the number of charging stations if demand increases.

2.1 Problem Description

This research was conducted in Semarang City which is a city located in Central Java Province. There are 16 Districts located in Semarang City and out of 16 Districts, several SPBU is scattered which are candidates for the location of the SPBU facility construction shown in Figure 1.

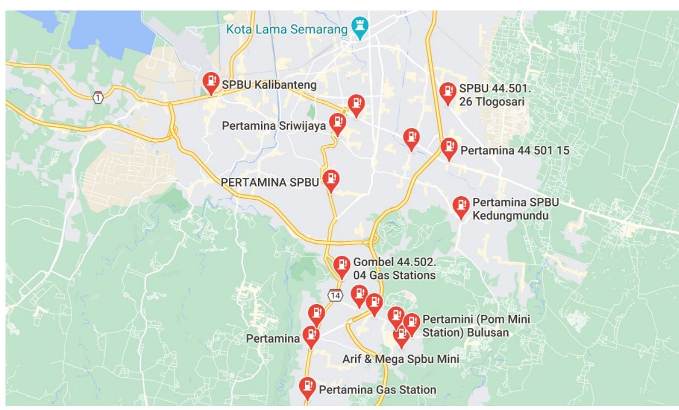

Figure 1. Candidate Location of Charging Station Facility

In designing a supply chain network, the important thing that is needed is the number of entities and supply chain flows. So it is necessary to create a supply chain network for the location of the charging station. Figure 2 describes the design process of the supply chain network.

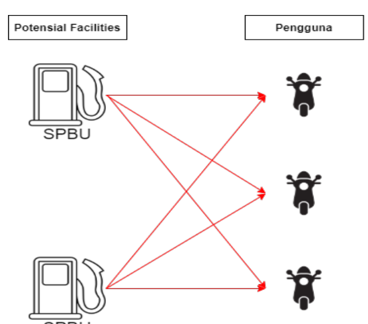

Figure 2. Supply Chain Network Design

2.2 Mathematical Modeling

The development carried out in this research is to look for several things, as follows: Minimizing the total distance from the charging station to the user or consumer, each user or consumer must be fully served and finding several many facilities to be built. The following is a mathematical model used in this study.

Objective Functions:

$$Z = Min \sum_{i \in I} \sum_{m \in M} F_{im} X_{im} + Min \sum_{i \in I} \sum_{j \in J} dist_{ij} C Y_{ij}$$

Coercion:

$$\sum_{i \in I} \sum_{m \in M} X_{im} Y_{i,j} \geq 1; \qquad \forall j \in J$$

$$Y_{ij} \leq \sum_{m \in M} X_{im}; \qquad \forall i \in I, j \in J$$

$$\sum_{j \in J} d_j Y_{ij} \leq \sum_{m \in M} Cap_m X_{im}, \qquad \forall i \in I$$

$$\sum_{m \in M} X_{im} \leq 1, \qquad \forall i \in I$$

$$\sum_{i \in I} \sum_{m \in M} X_{im} = P, \qquad \forall j \in J$$

$$X_{im} \in \{0,1\}, \forall i \in I, m \in M$$

$$Y_{ij} \in \{0,1\}, \forall i \in I, j \in J$$

The explanation for each notation is as follows:

I = Collection of charging station candidate sites
J = Collection of request points
M = Set charging station level
F_{im} = Investment cost to build charging station i level k
$dist_{ij}$ = Distance between charging station i to demand point j
C = Transportation costs per kilometer
d_j = request at node j
Cap_m = Filling station level service capacity k

$$X_{im} = \begin{cases} 1, \text{if we choose the candidate site } i \text{ and transform it into charging station level } m \\ 0, \text{otherwise} \end{cases}$$

$$Y_{ij} = \begin{cases} 1, \text{if demand point } j \text{ is covered by a charging station located at } i \\ 0, \text{otherwise} \end{cases}$$

The objective function (1) is to minimize transformation costs. Limitation (2) states that each demand point must be covered by at least one charging station. Limitation (3) means that the service can be offered only if the charging station is located at this candidate's location. Limitation (4) limits the service capacity of the charging station. Limitation (5) means that one candidate location can only be changed to one charging station. Constraint (6) means we want to find a facility P. Finally, constraints (7) and (8) are integral constraints.

The data collected will be processed using a distance-based approach with the help of using the ILOG CPLEX software, the results of data processing are to find the location of gas stations that will be used to build charging stations.

3. Result and Analysis

3.1 Case in Semarang City

The research was conducted in the city of Semarang which has 16 districts with the largest Mijen District. Vehicles used by the people of Semarang have not used Electric Vehicles (EV) as private vehicles, due to the lack of facilities for charging stations in Semarang City. Figure 3 is a map of Semarang City.

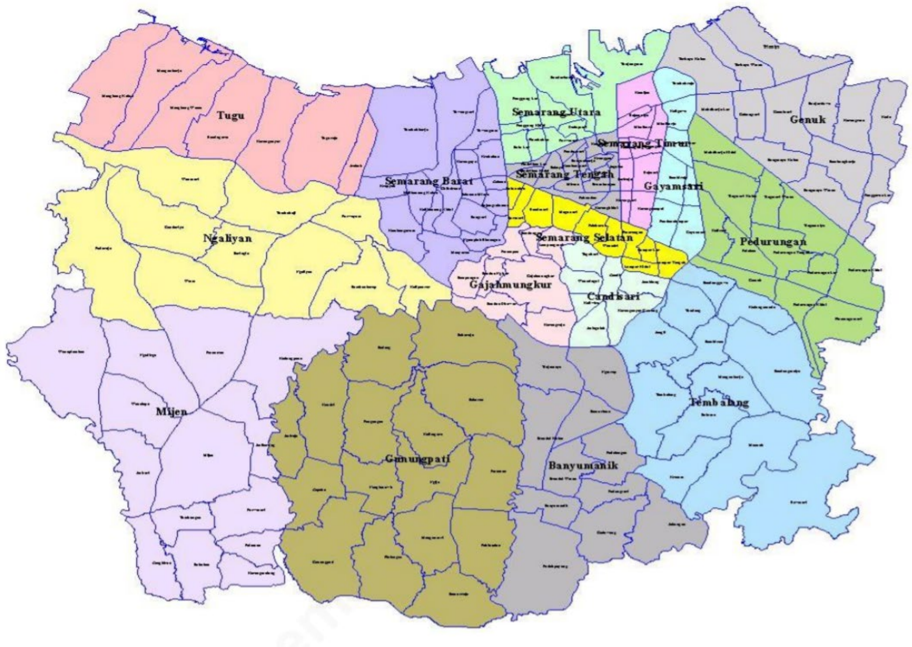

Figure 3. Map of Semarang City

Based on the results of the identification and data collection of districts in Semarang using Google Maps, there are 16 districts in Semarang City. The following Table 2 presents districts in Semarang City.

Table 2. List of Districts in Semarang City

No	Districts	Code
1	Semarang Tengah	A
2	Semarang Timur	B
3	Semarang Utara	C
4	Semarang Selatan	D
5	Semarang Barat	E
6	Tugu	F
7	Gajah Mungkur	G
8	Ngaliyan	H
9	Mijen	I
10	Gunungpati	J
11	Candisari	K
12	Genuk	L
13	Gayamsari	M
14	Pedurungan	N
15	Banyumanik	O
16	Tembalang	P

Based on the results of the identification and data collection of gas stations in Semarang using Google Maps, there are 69 gas stations located in Semarang City. The following Figure 4 and Table 3 presents the coordinates of the charging station candidate locations.

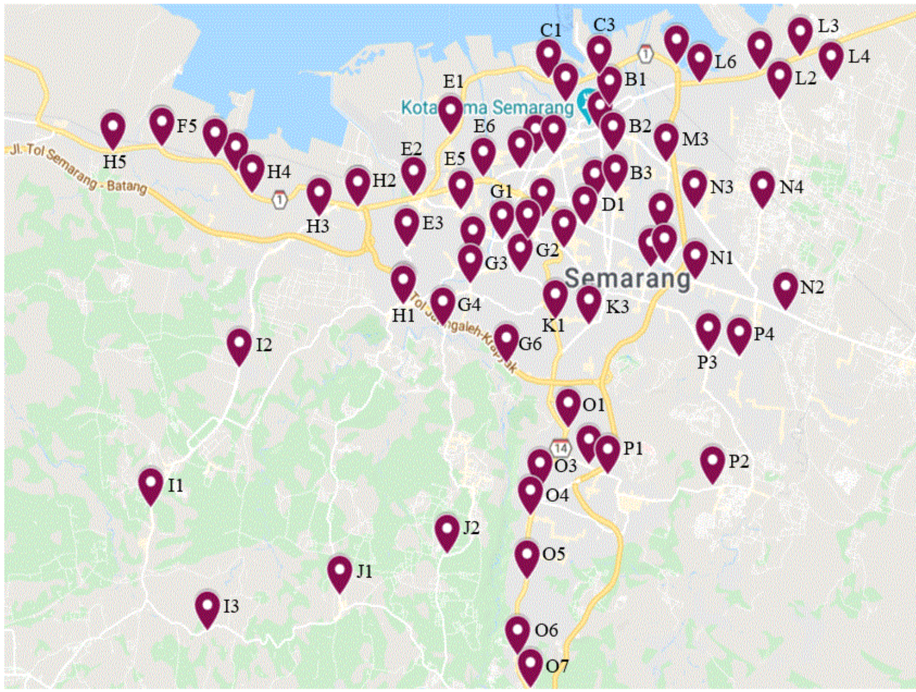

Figure 4. Candidate Location of Charging Station Facility

Table 3. List of SPBU in Semarang City

No	Potential Facilities	Coordinate
1	A1	-6.978500, 110.409653
2	A2	-6.974667, 110.413577
3	A3	-6.975099, 110.418611
4	A4	-6.985755, 110.429526
5	A5	-6.969062, 110.430288
6	B1	-6.962993, 110.433183
7	B2	-6.974120, 110.434436
8	B3	-6.984823, 110.434880
9	C1	-6.956487, 110.416055
10	C2	-6.961961, 110.421723
11	C3	-6.955095, 110.430646
12	D1	-6.992565, 110.426947
13	D2	-6.990779, 110.415459
14	D3	-7.003090, 110.444166
15	E1	-6.970186, 110.390964
16	E2	-6.985522, 110.381172
17	E3	-6.997904, 110.379449
18	E4	-7.012003, 110.378688
19	E5	-6.988795, 110.393860
20	E6	-6.980635, 110.399663

No	Potential Facilities	Coordinate
21	E7	-7.000154, 110.396738
22	F1	-6.988222, 110.366121
23	F2	-6.979242, 110.333512
24	F3	-6.972956, 110.313876
25	F4	-6.975805, 110.328280
26	F5	-6.973000, 110.314000
27	G1	-6.996233, 110.404788
28	G2	-7.004491, 110.409394
29	G3	-7.007251, 110.396279
30	G4	-7.017611, 110.388857
31	G5	-6.996077, 110.411641
32	G6	-7.026795, 110.405835
33	H1	-7.012145, 110.378408
34	H2	-6.988212, 110.366091
35	H3	-6.990571, 110.355899
36	H4	-6.984773, 110.338046
37	H5	-6.974162, 110.301149
38	I1	-7.062838, 110.310899
39	I2	-7.028125, 110.334811
40	I3	-7.093253, 110.326127
41	J1	-7.084653, 110.361555
42	J2	-7.074297, 110.389991
43	K1	-7.015991, 110.418665
44	K2	-6.998296, 110.421104
45	K3	-7.017305, 110.427715
46	L1	-6.954083, 110.473323
47	L2	-6.961599, 110.478437
48	L3	-6.950627, 110.483843
49	L4	-6.956729, 110.492152
50	L5	-6.952722, 110.451159
51	L6	-6.957015, 110.457165
52	M1	-6.994140, 110.446811
53	M2	-7.002075, 110.447908
54	M3	-6.976922, 110.448268
55	N1	-7.006070, 110.456028
56	N2	-7.014152, 110.480187
57	N3	-6.988469, 110.455952
58	N4	-6.988825, 110.474040
59	O1	-7.042810, 110.422092
60	O2	-7.052086, 110.427763

No	Potential Facilities	Coordinate
61	O3	-7.058060, 110.414668
62	O4	-7.064890, 110.412415
63	O5	-7.080738, 110.411288
64	O6	-7.099565, 110.408754
65	O7	-7.107797, 110.412101
66	P1	-7.054661, 110.432700
67	P2	-7.057429, 110.460804
68	P3	-7.024290, 110.459731
69	P4	-7.025238, 110.467842

3.2 Numeric Example

In this study, all residents or communities are assumed to own a motorbike. The number of charging requests is assumed to be the same as the number of E-Motorcycle users. Population data is obtained through the Semarang Statistics Central Agency website. Table 4 shows the population data of Semarang City.

Table 4. Data on Population of Semarang City in 2019

No	Districts	An Area	Total Population	
			n	%
1	Semarang Tengah	6,14	61.102	3,37%
2	Semarang Timur	7,70	75.762	4,18%
3	Semarang Utara	10,97	119.647	6,60%
4	Semarang Selatan	5,93	70.522	3,89%
5	Semarang Barat	21,74	165.048	9,10%
6	Tugu	31,78	33.333	1,84%
7	Gajah Mungkur	9,07	60.679	3,34%
8	Ngaliyan	37,99	165.171	9,10%
9	Mijen	57,55	76.037	4,19%
10	Gunungpati	54,11	118.760	6,55%
11	Candisari	6,54	76.857	4,24%
12	Genuk	27,39	119.010	6,56%
13	Gayamsari	6,18	83.036	4,57%
14	Pedurungan	20,72	214.689	11,83%
15	Banyumanik	25,69	164.953	9,09%
16	Tembalang	44,20	209.504	11,55%
	Total	373,70	1.814.110	100,00%

3.3 Result

From the results of the operation using the ILOG CPLEX, it was found that the optimum results from the charging station locations were 4 location points with each sub-district having one charging station with details as follows.

Table 5. Selected Charging Station Candidates

No.	Name of SPBU	Semarang Tengah	Semarang Timur	Semarang Utara	Semarang Selatan	Semarang Barat	Tugu	Gajah Mungkur	Ngaliyan	Mijen	Gunungpati	Candisari	Genuk	Gayamsari	Pedurungan	Banyumanik	Tembalang
1	E2	v		v		v	v	v	v								
2	J1									v	v						
3	N3		v		v								v	v	v		
4	O2											v				v	v

From 4 points the location of this charging station can maximize the coverage of the selected sub-districts and with the decision of 1 location point in each district, so that this result can answer the goal. If this model is applied, it will cause several risks, including the uncertainty of total costs when the government decides to open more charging stations so that the government cannot estimate the budget funds needed for the charging station construction project. And another risk is that the government cannot anticipate queues and estimate the number of queues at the charging station. This is because the model doesn't consider scheduling and traffic jams. Therefore for further research.

4. Conclusion

The development of a supply chain network model for the charging station case in Semarang has been carried out. The model has been run considering the location of the selected candidate filling station. This model can provide input to local governments regarding the optimal solution in determining the location of E-Motorcycle charging stations. However, the weakness of this model is that it still uses numerical examples in determining the demand for E-Motorcycle users, so the results obtained do not fully cover the demand in Semarang City. Therefore, the shortcomings and limitations of this model need to be accommodated in further research by improving data collection and processing methods and adding scheduling parameters, traffic density and maximum battery capacity and recharging duration to the model.

Acknowledgments

This research was supported by the Students Exchange of *Merdeka Belajar Kampus Merdeka (MBKM)* Program between the Department of Industrial Engineering Universitas Sebelas Maret and Universitas Diponegoro.

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Biography

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