Optimization of Network Design for Charging Station of Electric Car with Center of Gravity Method: A Case Study

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Abstract

The import of gasoline is one of the biggest causes of the deficit in the country of Indonesia. Indonesia has committed to reducing CO2 emissions. Electric vehicles can be a solution to reduce dependence on gasoline and reduce CO2 emissions significantly. Sebelas Maret University is appointed by the Ministry of Education and Culture to develop an electric car vehicle named Mobil Listrik Nasional (Molina). However, the charging station is nowhere to be found in the city of the university, Surakarta. A charging station is urgently needed to popularize electric vehicles and reduce its technology bottleneck. This study aims to optimize the location selection to build a charging station facility in the city of Surakarta. The method used is a center of gravity method and software called Microsoft Excel. The result is optimum charging location for electric car vehicles that minimize total cost. This study proposes a recommendation to the city government or Sebelas Maret University to support the acceleration of electric vehicles, especially Molina in the city of Surakarta.

Keywords
Charging station, Distance-based model, Lingo, Mobil Listrik Nasional (Molina)

1. Introduction

In the last ten years, energy consumption in Indonesia kept increasing, around 7-8% per year (Akhmad & Amir, 2018). Unfortunately, Indonesia's energy consumption is relying through import (Ministry of Energy and Mineral Resources, 2016). On top of that, gasoline import is one of the biggest cause of the deficit in Indonesia (Budiantoro, 2019). Majority energy consumption in Indonesia comes from fuel oil or Bahan Bakar Minyak (BBM), around 90% of it. And its fuel oil consumption 88% comes from transportation sector. The total number of vehicle from this sector growth is increasing every year, around 6-7% (Secretary of National Energy, 2016). Its expected that energy consumption will causing more and more deficit for Indonesia.

Indonesia also had a carbon emission issue. It has too much greenhouse gases in atmosphere. Greenhouse gasses presence in the atmosphere is becomes too excessive because of burning petroleum and if this gas keep continue accumulate it can causes climate change (Nurdiawansyah & Lindrianasari, 2018). Climate change is a major

problem not only for Indonesia but in the world. To response this problem Indonesia in the United Nation Conference (COP21) 2015 commit to reduce its emission up to 29% or 303 million tons in 2030. Several solution for this aims can be achieved, and one of them are implementation of electric vehicle in the society.

Electric vehicle is one of the solution for both fuel oil consumption and emission problem. It consume zero fuel and produce zero emission, pure electric which can be achieved by sustainable electric generator such as turbine, solar etc. In addition, the automotive industry is the greatest industrial sector (Mathivathanan et al., 2018), any change in this sector will affect significant change in the society. Recently, innovation in this sector is become a hot topic after Tesla Motors release their high end electric cars to the market. Tesla was the only manufacturer who sell zero-emission electric vehicle sport cars in the world (Mangram, 2012). The trends keep increasing, more electric vehicle manufacturer come to the market such as Rivian, Nio and even some petrol car vehicle producing electric vehicle now.

Indonesia appoint universities to develop electric car vehicle. One of them is Sebelas Maret University (UNS), develop car electric vehicle called Mobil Listrik Nasional (Molina) (Wicaksana et al, 2014). It located in Surakarta. This is a good first step to popularize electric vehicle in Indonesia. Their first product called SMART EV.1, a city car that has a capacity of four people with BLDC 3 kW motor and 3kW lead acid battery developed in 2009. In 2012 UNS get a grant from Directorate of Research and Community Service and succeeded in producing one more prototype product called SMART EV.2 and the innovation is keep going.

Although the development of electric cars has been seen, the development of charging stations is still not prominent. Meanwhile, one of the problem in electric vehicle development is range anxiety. Range anxiety is a fear that vehicle has insufficient range to reach destinations. The main problem of this fear is the lack of charging station. To solve this problem charging station infrastructure need to built to accelerate electric vehicle popularity and eliminate technology bottleneck (Aqidawati et al, 2021). Distance-based method can be used to determine charging station location. With this method we can achieved the best location to build charging station.

1.1 Objectives

This paper aims to capture the best location planned to build new facility for charging station infrastructure with distance-based method on the choosen SPBU.

2. Literature Review

Charging station infrastructure study had been conducted by several researchers. Khofiyah et al., (2021) proposed an optimum location for 3-wheeled electric vehicle charging station using IBM ILOG CPLEX Optimization considering demand maximization and cost minimization in Surakarta. Akbari et al. (2018) is using genetic algorithm to minimize the total charging cost with several mode or scenario: slow, medium, and ultra-fast charging mode. The output are theh right charging mode and suitable charging location. Aqidawati et al. (2021) propose a supply chain network for chargnig station facility in Surakarta. Gas station had been choosen as potential location to build charging stations.

3. Methods

The methods used in this research are heavily influenced by Khofiyah et al., (2021) and Aqidawati et al., (2021). This study take place in Surakarta and fuel charging stations called Stasiun Pengisian Bahan Bakar Umum (SPBU) are used as candidate for new charging station point. Each demand will be categorize based on district called Banjarsari, Jebres, Laweyan, Pasar Kliwon, Serengan.

4. Data Collection

Data had been collected from previous research and Badan Pusat Statistika (BPS) Surakarta. Government targets 20% of total car vehicle will be low carbon emission vehicles in 2025 (Jelita, 2021). Demand for electric car determined by assumption that 5% of total car available in the district will be electric vehicle in the future based on Aqidawati et al. (2021) . Distance-based method and Microsoft Excel Solver had been used.

5. Results and Discussion

Data collected from various sources are represented in Table 1.

Table 1. Demand for Charging Station

Demand Point	Population	Demand
Banjarsari	183541	1297
Jebres	147694	1044
Laweyan	102524	725
Pasar Kliwon	86890	614
Serengan	54671	386

Source: Processed data from Badan Pusat Statistika (BPS) Surakarta and Unit Pengelolaan Pendapatan Daerah (UPPD) Surakarta

Population data for Table 1 had been collected from Badan Pusat Statistika (BPS) Surakarta and demand had been collected by processing data with the assumptions of government targets from Unit Pengelolaan Pendapatan Daerah (UPPD) Surakarta. Charging station candidates can be seen in Table 2 below.

Table 2. SPBU Coordinate

No	No. SPBU	Latitude (x)	Longitude (y)	Market area (n)
1	4357101	-7,554966	110,801878	Laweyan
2	4457102	-7,569535	110,852133	Jebres
3	4457103	-7,540473	110,806821	Banjarsari
4	4457108	-7,580494	110,815183	Serengan
5	4457119	-7,559267	110,848661	Jebres
6	4457111	-7,541805	110,815823	Banjarsari
7	4457115	-7,531215	110,819126	Banjarsari
8	4457117	-7,578938	110,831107	Pasar Kliwon
9	4457120	-7,545629	110,807277	Banjarsari
10	4457121	-7,554863	110,811484	Banjarsari
11	4457123	-7,573652	110,810178	Laweyan
12	4457124	-7,557442	110,823444	Banjarsari
13	4457126	-7,550865	110,829719	Banjarsari
14	4457127	-7,571100	110,801322	Laweyan
15	4457104	-7,568286	110,786620	Laweyan
16	4457116	-7,544113	110,839960	Jebres
17	4457128	-7,556273	110,851003	Jebres
18	4457125	-7,585991	110,834031	Pasar Kliwon
19	4457109	-7,564810	110,857901	Jebres
20	4357102	-7,561299	110,817677	Banjarsari

Source: Aqidawati et al., (2021)

Table 3 shows district geographic location with latitude and longitude. To simplify table, each district is represented by alphabet, A = Banjarsari, B = Jebres, C = Laweyan, D = Pasar Kliwon, and E = Serengan. Data for Table 2 and Table 3 had been collected from Aqidawati et al. (2021).

Table 3 District Coordinate

Kecamatan	Latitude	Longitude
Laweyan	-7,571289	110,808949
Serengan	-7,580754	110,815107
Pasar Kliwon	-7,586689	110,828221
Jebres	-7,555101	110,855164
Banjarsari	-7,542316	110,810299

Source: Aqidawati et al., (2021)

The formulation to process data above can be seen below.

Maximum $F(X, Y) = \sum_{i=1}^{m} \sum_{j=1}^{n} W_j \, . \, D_i$

$$D = \sqrt{(Xi - Aj)^2 + (Yi - Bj)^2}$$

Where,
D = distance
m = alternatives
n = markets
W = demand
X ; Y = alternatives coordinate
A ; B = market coordinate

Data had been processed with formulation above using software Microsoft Excel and the result can be seen in Table 4 below.

Table 4. Processed data with center of gravity method

Number of SPBU	Market area (n)	Distance (D)	Demand (W)	d.W
4457103	Banjarsari	0,004	1297	5,105162854
4457111		0,006	1297	7,195217472
4457115		0,014	1297	18,39492307
4457120		0,004	1297	5,816065733
4457121		0,013	1297	16,34587617
4457124		0,020	1297	25,99140433
4457126		0,021	1297	27,52030461
4357102		0,020	1297	26,41518654
		Total		**132,7841408**
4457102	Jebres	0,015	1044	15,39775483
4457119		0,008	1044	8,062800915
4457116		0,019	1044	19,58433141
4457128		0,004	1044	4,513112501
4457109		0,010	1044	10,53125653
		Total		**58,08925619**

Table 4. Processed data with center of gravity method (continued)

Number of SPBU	Market area (n)	Distance (D)	Demand (W)	d.W
4357101	Laweyan	0,018	725	12,89683852
4457123		0,003	725	1,931034472
4457127		0,008	725	5,531272506
4457104		0,023	725	16,33427172
		Total		**36,69341722**
4457117	Pasar Kliwon	0,008	614	5,078303284
4457125		0,006	614	3,5929916
		Total		**8,671294883**
4457108	Serengan	0,000	386	0,104559698
		Total		**0,104559698**

The result shows that Banjarsari district had the highest weight of demand with result 132,7841408. So the charging station should be placed in Banjarsari district. The closest distance between SPBU and Banjarsari district is SPBU No. 4457103. SPBU No. 4457103 named SPBU Banyuanyar located in Jl. Adi Sumarmo No.168, Banyuanyar, Kec. Banjarsari. By this result Mobil Listrik Nasional (Molina) can start to focusing market in Banjarsari which has the highest demand among other district and considering build charging station in SPBU Banjarsari to accelerate development.

6. Conclusions

Charging station is the most important aspect to solve range anxiety and to accelerate electric vehicle development. This research is considering SPBU distance and demand in each district to find the best location to build charging station using center of gravity method and Microsoft Excel. The result shows that SPBU Banjarsari located in Banjarsari is the best location to build first charging station in Surakarta to accelerate Mobil Listrik Nasional (Molina) technology commercialization.

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