Charging Station Network Design for E-Motorcycle: A Case Study

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Abstract

E-motorcycle technology is an attractive option to be developed in Indonesia because of the large number of motorcycle users. It can grow rapidly in the market if it is supported by charging facilities. To anticipate the development of e-motorcycle usage in the city of Surakarta, it is necessary to plan and design a network of this charging facility. This study proposes a supply chain network model for charging station facilities in the city of Surakarta with the aim of achieving the greatest possible coverage with the least number of charging stations and the minimum investment costs. Gas stations spread across the city are potential locations to be chosen as charging stations. The model used to solve the problem is built from a combination and modification of the models in relevant previous studies. The integer linear programming method is used to achieve optimal solutions and the model is run using CPLEX with four different scenarios. The model generates selected candidates site and determines which candidate sites are the supply for each demand point. The results of this study are expected to provide insight, recommendations and input to the city government of Surakarta to support the acceleration of e-motorcycle usage.

Keywords
e-motorcycle, charging station, facility location, supply chain network design

1. Introduction

Electric motorcycle is considered as a new transportation to reduce gas emission and promote environmental sustainability (Lukic and Pantic, 2013; Mak et al, 2013; Nosi et al, 2017). Electric motorcycles have an electric motor and a battery to store the energy needed to drive the vehicle. The known charging patterns include conductive, inductive and battery replacement (Ahmad et al, 2018; Rahmawatie et al, 2017). The conductive method is done by connecting an electric vehicle with an electricity supply cable (Dericioglu et al, 2018). The number of power levels supplied during electric charging determines the length of the charging process. There are three levels of filling namely slow, medium and fast charging (Martinez et al, 2017). The inductive method occurs via electromagnetic transmission without any contact between the electric vehicle and the charging infrastructure (Ahmad et al, 2018; Karakitsios et al, 2014; Lu et al, 2016). The swap method is carried out by swapping an empty swap battery with a swap battery that is fully charged (Huang, 2016). To popularize electric motorcycles, with the exception of the high price and the unresolved technological bottleneck, we should consider the development of charging facilities as a precondition.

In fact, the implementation of charging stations providing a fast charging service is our priority. Their presence will relieve the fears of common users regarding the travel recharging process and will significantly promote the spread of electric vehicles and minimize carbon emissions, achieving an energy-saving goal. A precondition for the commercialization and industrialization of the electric motorcycle is the development of a highly productive energy supply network. Therefore, the study of charging stations deployment has practical significance. In this paper, we propose the concept of considering conventional gas stations as candidate sites and develop model based on previous researches in order to generate charging station network. It takes advantage of the current gas stations network and makes the early decision-making process easy. We also performed a computational experiment to validate our model and algorithm.

There have been various studies on electric vehicles (Sutopo and Kadir, 2017; Sutopo et al, 2018; Sutopo and Kadir, 2018; Rahmawatie et al, 2017; Atikah et al, 2014; Aristyawati et al, 2016; Sutopo et al, 2013; Prianjani et al, 2016; Waloyo et al, 2018; Sutopo et al, 2018) and supply chain network design (Lupita et al, 2017; Wahyudin et al, 2015; Sutopo et al, 2014; Sutopo et al, 2013; Aqidawati et al, 2018). In addition, there are also several studies related to the development of network models and charging station locations. Mehar and Senouci (2013) minimize the cost of developing a charging station to meet customer demands. Chen and Hua (2014) minimized the cost of transformation in selecting candidate locations to convert into charging stations. Zeng et al (2019) developed a cost-effective BSS while meeting the demand for swap batteries in metropolitan areas. Giménez et al (2016) maximized the number of potential users with minimum daily access times. Cruz et al (2019) minimized construction costs and the value of energy losses from the system for the selection of the charging station location. Sun et al (2019) found optimal battery purchase and charging policies that provide the greatest trade off of investment costs and battery operating costs. Kong et al (2019) minimized the total construction cost of all filling stations by determining the location and size of filling stations. Fazeli et al (2020) maximizes the expected access of EV drivers to the charging station and maximizes EV traffic flow.

E-motorcycle technology is an attractive option to develop in Indonesia because of the large number of motorcycle users. In addition, there are several e-motor cycles that have started circulating in the Indonesian market. E-motorcycles can grow rapidly if they are supported by facilities in certain areas that can be used to exchange batteries or recharge batteries, because the batteries used certainly have maximum capacity so that electric vehicles also have limited mileage. This recharging cannot be done just anywhere because it requires a lot of power, so it is necessary to build a separate charging facility. To anticipate the development of e-motorcycle usage in the city of Surakarta, it is necessary to plan and design a network of this charging facility. This of course also takes into account the limited costs and the fulfillment of the needs of all electric vehicle users in Surakarta, which are spread across five districts. Therefore, we need the right supply chain network model to achieve these goals. This study proposes a supply chain network model for charging station facilities in the city of Surakarta with the aim of achieving the greatest possible coverage with the least number of charging stations and the minimum investment costs. Refueling stations that are scattered in the city are potential locations to be chosen as charging stations. Gas station is seen as a potential and more efficient solution due to its already considered and strategic location.

2. Methods

The problem situation is described as follows. There are five districts in Surakarta, namely A, B, C, D and E. These five districts are defined as demand points in this study. In each district there are several gas stations, which are shown in Figure 1. These gas stations are candidate locations for the construction of charging station facilities.

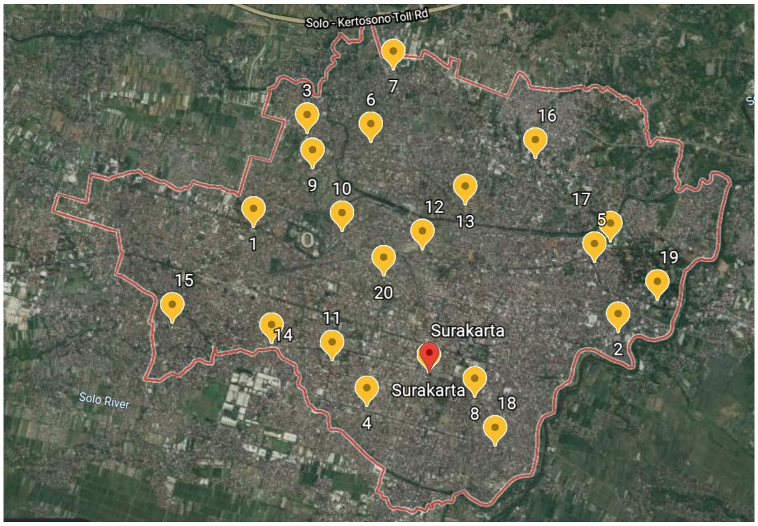

Figure 1. The location of charging station candidate sites

Apart from the number and location, the charging station network designed in this study also considers the size aspect of its facilities. This means that there are several scenarios for the type / level of the charging station to be built. This of course affects the service capacity that can be offered and the investment costs for converting gas stations and building them into charging stations. Apart from investment costs, transportation costs are also considered in this model. The distance from the demand point to the charging station location determines the amount of transportation costs.

The purpose of this study is to produce a charging station network design by considering the coverage of all demand points, the minimum possible investment costs within a specified time period. The key decisions in this study are that the government must decide how many charging stations to build, where they are and what the charging station levels are. The purpose of this model is to minimize investment costs and transportation costs. Parameters that can change are charging demand because it is an uncertain variable and transportation cost parameters because it depends on the distance between the charging station location and the demand point. In addition, the investment cost to build a charging station can also change according to the level of the chosen charging station. Meanwhile, the constant factors are the location of the charging station and the types of vehicles served.

The model in this study is a development of the model in the research of Mehar and Senouci (2013) and Chen and Hua (2014). Both of these studies are developing a model for choosing a charging station location. Table 1 illustrates the comparison between the two models.

Table 1. Models comparison

Aspect	Mehar and Senouci (2013)	Chen and Hua (2014)
Performance criteria	• investment costs for charging station construction i • User j's transportation costs to the charging station i	Transformation cost of grade m filling station for candidate j

Aspect	Mehar and Senouci (2013)	Chen and Hua (2014)
Constraint	• One user may only charge at one charging station • The total energy used to charge (energy demand) does not exceed the capacity of the charging station	• each point of demand must be covered by at least one charging station • service can be offered only if the charging station is located at this candidate's location • limitation of filling station service capacity • one candidate location can only be changed to one tier charging station
Alternative solution	Heuristic solutions; the authors adapted the genetic algorithm to solve the problem of charging station location, add new operators to the classical genetic algorithm to prevent premature convergence and increase the efficiency of the algorithm. The resulting solution: determine the number of charging stations needed and the best location	The authors proposed a new location model based on a set cover model that takes the existing traditional gas station network as a candidate location to determine the distribution of charging and battery exchange stations.
Analytical approach	TAPAS Cologne simulation scenario depicts traffic in the city of Cologne (Germany), calculated using OLoCs to find the best position of the charging station	Using the pure integer linear problem (PILP) approach because there are several level charging stations to be built (multi-level location problems)
Method of collecting data	scenarios based on information about the user's traveling habits	Primary and secondary data The total planning for the number of filling stations is obtained from the government plan and the specific number of filling stations in each region is obtained through the spatial forecasting model.
Data validation	compared the author's approach with the exact solution produced by CPLEX	-
Application / software	Matlab	LINGO
Output	genetic algorithms for optimal placement of charging stations (oLoCs)	Recommendations for the government

Based on the problem statement and references to the two models above, we can determine the data needed to solve the problem. Charging demand is assumed to be the same as the demand for electric motorcycles which refers to the market share prediction from the research of Jodinesa et al (2020). In addition, the investment costs for charging station construction and charging station capacity are dummy data in the form of numerical examples. Furthermore, data on the coordinates of gas stations and sub-district locations in Surakarta were collected through Google Maps and Google Earth. Then the distance data between the gas station and the district is obtained through calculations using the formula:

$$d = 2r\sin^{-1}\left(\sqrt{\sin^2\left(\frac{\Phi_2-\Phi_1}{2}\right)+\cos(\Phi_1)\cos(\Phi_2)\sin^2\left(\frac{\lambda_2-\lambda_1}{2}\right)}\right) \quad (1)$$

The first step in model development is defining the problem situation to identify the entities and variables involved. After that, we conducted a literature review to find a reference model that suited the problem conditions. Then, we compare the two reference models and see their characteristics, as described in Table 2. The next step is to adjust and balance the notation and variables in the two models. Furthermore, the influence diagram is made based on the problem statement already described. Influence diagrams are made to determine the relationship between variables, as shown in Figure 2. Finally, the model is combined by considering the influence diagrams that have been made so that the following mathematical model formulation can be obtained.

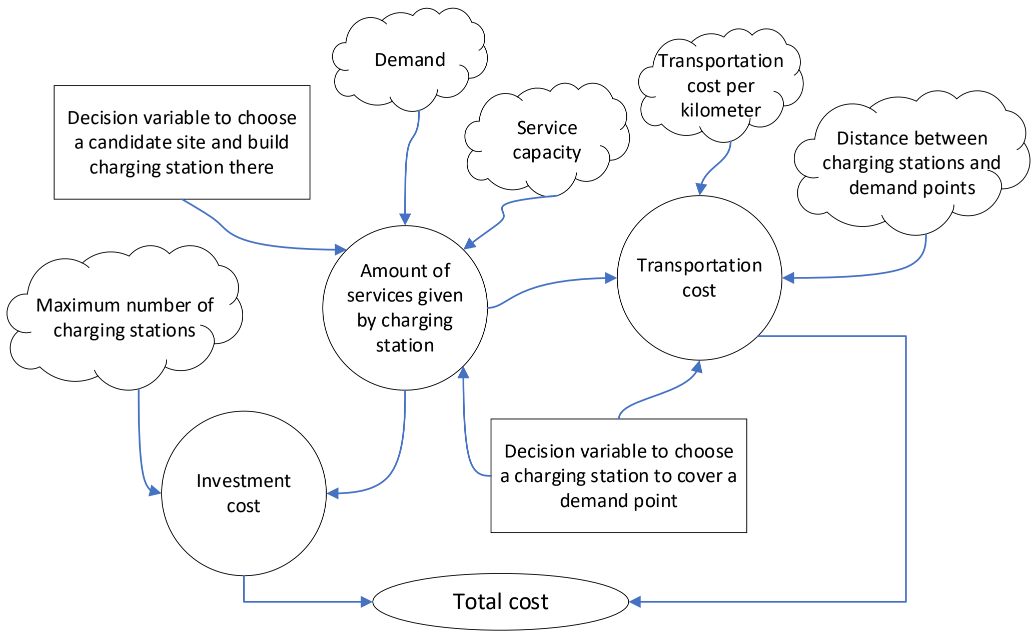

Figure 2. Influence diagram

The objective function is formulated as follows:

$$Z = \min \sum_{i \in I} \sum_{k \in K} A_{ik} X_{ik} + \sum_{i \in I} \sum_{j \in J} dist_{ij} \, C \, Y_{ij} \quad (2)$$

Meanwhile the constraints are formulated as follows:

$$\sum_{i \in I} \sum_{k \in K} X_{ik} Y_{ij} \geq 1, \ \forall j \in J \quad (3)$$
$$Y_{ij} \leq \sum_{k \in K} X_{ik}, \ \forall i \in I, j \in J \quad (4)$$
$$\sum_{j \in J} D_j Y_{ij} \leq \sum_{k \in K} Cap_k X_{ik}, \ \forall i \in I \quad (5)$$
$$\sum_{k \in K} X_{ik} \leq 1, \ \forall i \in I \quad (6)$$
$$\sum_{i \in I} \sum_{k \in K} X_{ik} = P, \ \forall j \in J \quad (7)$$
$$X_{ik} \in \{0,1\}, \forall i \in I, k \in K \quad (8)$$
$$Y_{ij} \in \{0,1\}, \forall i \in I, j \in J \quad (9)$$

The descriptions for each notation are as follows:
I : The set of charging station candidate sites
J : The set of demand points
K : Set of charging station levels
A_{ik} : Investment cost to build charging station at candidate site i level k
$dist_{ij}$: The distance between candidate site i to demand point j
C : Transportation cost per kilometer
P : Maximum number of charging stations that want to be built
D_j : Demand at node j
Cap_k : The service capacity of charging station level k

$$X_{ik} = \begin{cases} 1, \text{if we choose the candidate site } i \text{ and build charging station level } k \text{ there} \\ 0, \text{otherwise} \end{cases}$$
$$Y_{ij} = \begin{cases} 1, \text{if demand point } j \text{ is covered by a charging station located at } i \\ 0, \text{otherwise} \end{cases}$$

The objective function (2) is to minimize the total cost including investment and transportation cost. Constraint (3) indicates that at least one charging station should cover each demand point. Constraint (4) means that only if the charge station is in this candidate's location will the service be provided. Constraint (5) indicates that the services provided by the selected charging station must not exceed its capacity. Constraint (6) means that we can only build one kind (level) of charging station at the chosen candidate site. Constraint (7) means we want to locate exactly P facilities. Finally, constraints (8) and (9) state that the decision variables in this model are a binary number.

3. Results and discussion

In this study, all residents are assumed to own a motorcycle. The number of charging requests is assumed to be the same as the number of electric motorcycle users. In this case, the number of users of electric motorcycles refers to the market share prediction that has been made by Jodinesa et al (2020). The number of users of electric motorcycles is determined by multiplying the market share of 36% by the total population. Population data were obtained through the website of the Surakarta Central Statistics Agency. Table 2 shows the charging demand for each district.

Table 2. Charging demand

Demand point	Number of citizens	Demand
A	102,524	36909
B	54,671	19682
C	86,890	31280
D	147,694	53170
E	183,541	66075

Based on the results of identification and data collection of gas stations in Surakarta through Google Maps, as many as 20 gas stations were identified. Google Earth is used to find the latitude and longitude points of each gas station and district. A set of location coordinates of the demand points and charging station candidates were obtained. Table 3 shows the results of the calculation of the distance between the location of the charging station candidate and the location of the demand point based on the latitude and longitude coordinates.

Table 3. Distance between charging station *i* to demand point *j* (in kilometer)

Charging station candidate	Distance to demand point				
	A	B	C	D	E
1	1.98	3.22	4.57	5.87	1.69
2	4.76	4.27	3.25	1.64	5.52
3	3.43	4.57	5.65	5.57	0.43
4	1.23	0.03	1.59	5.23	4.28
5	4.58	4.40	3.79	0.85	4.63
6	3.36	4.33	5.17	4.58	0.61
7	4.60	5.53	6.25	4.78	1.57
8	2.59	1.78	0.92	3.75	4.67
9	2.86	4.00	5.12	5.38	0.50
10	1.85	2.91	3.99	4.81	1.40

Charging station candidate	Distance to demand point				
	A	B	C	D	E
11	0.30	0.96	2.46	5.37	3.48
12	2.22	2.75	3.29	3.51	2.22
13	3.22	3.69	3.99	2.84	2.34
14	0.84	1.86	3.43	6.20	3.35
15	2.48	3.43	5.02	7.70	3.89
16	4.56	4.91	4.91	2.07	3.28
17	4.93	4.80	4.21	0.48	4.75
18	3.21	2.17	0.65	4.15	5.52
19	5.44	5.04	4.08	1.12	5.81
20	1.47	2.18	3.05	4.19	2.26

Transportation costs are defined as the product of the distance traveled by the user and the cost for energy expended per kilometer. The transportation cost per km is assumed to be IDR 300,000. In addition, data on the investment costs for charging station construction and service capacity are also assumed and defined for each charging station level, which is shown in Table 4.

Table 4. Service capacity and investment cost for charging station level *k*

Level	Service capacity	Investment cost
1	325,000	1,761,290,323
2	225,000	1,219,354,839
3	80,000	433,548,387

The formulated model is running with the collected data using CPLEX. CPLEX uses decision optimization technology to optimize business decisions, develop and deploy optimization models quickly, and create real-world applications that can significantly improve business outcomes. CPLEX enables rapid development and deployment of decision optimization models using mathematical and constraint programming. The model is run with four different scenarios, namely when the maximum number of charging stations (P) is 3, 4, 5, and 6. Figure 3 illustrates the problem solving approach.

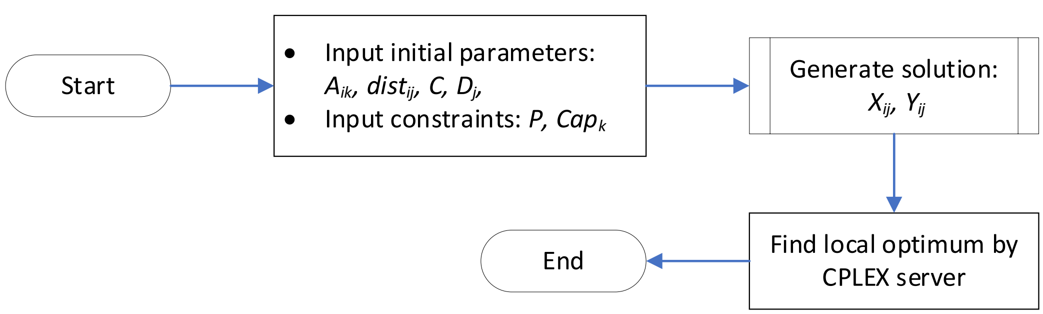

Figure 3. Problem solving approach

Table 5 shows the results of the objective function and the total time needed to find the optimal solution. Based on this table, the Z values in the scenario P = 5 and P = 6 are not found and the settlement time is also very long. This may happen because the model is already in a steady state condition or it could be due to the effect of data collection in the form of dummy data so that it is less able to represent the problem.

Table 5. Objective function result

Max number of charging station (P)	Z	Time
3	1,303,177,161	3 minutes 32 seconds
4	1,735,039,548	33 seconds
5	-	6 minutes
6	-	14 minutes

The results of decision variable X_{ik} were generated. In scenario P = 3, CS 3, CS 5, and CS 11 were selected. CS 3, CS 4, CS 17, and CS 18 were selected for scenario P = 4. Meanwhile CS 3, CS 4, CS 11, CS 17, and CS 18 were selected for scenario P = 5. Furthermore, in scenario P = 6, CS 3, CS 4, CS 8, CS 11, CS 17, and CS 18 were selected. Based on the results, the model tends to choose the level 3 charging station. This is because level 3 has the cheapest investment cost and its value is much smaller than the other levels. The use of dummy data for parameters of investment costs and service capacity can also be the cause of the absence of level variations at the chosen charging station. This means that a systematic calculation should first be carried out to determine these two parameters so that the results are more varied.

The results for decision variable Y_{ij} were also generated. This result shows which candidate locations are assigned as the supplier for each demand point. In scenario P = 3, three candidate sites were selected. CS 3 would be opened to satisfy demand point E, CS 5 would be opened to satisfy demand point B and D, whereas CS 11 would be opened to satisfy demand point A and C. In scenario P = 4, four candidate sited were selected. CS 3 would be built to satisfy demand point E, CS 4 would be built to satisfy demand point A and B, whereas CS 17 and 18 would be built to satisfy demand point D and C respectively. The thing that needs to be underlined is that the scenario P = 5 and P = 6 show the same result. This is because there are five demand points, so at P = 6, the model also only shows five gas stations that would act as suppliers. In the scenario P = 5 and P = 6, demand point A would be supplied by CS 11, demand point B would be supplied by CS 4, demand point C by CS 18, demand point D by CS 17, and demand point E would be satisfied by CS 3.

Based on the value of the decision variables obtained, the model proposed in this study is considered as integer linear programming (ILP) problem. ILP is a linear integer programming model that can produce solutions with both integer and non-integer values. It can be seen that the value of both X_{ij} and Y_{ij} is either 0 or 1. Based on the results and analysis, this model succeeded in providing a solution for the location of the charging station construction. In the scenario P = 3, P = 4, P = 5, P = 6, the selected locations are {3,5,11}, {3,4,17,18}, {3,4,11,17,18}, {3,4,8,11,17,18}. The level chosen for all scenarios is level 3. This model is not very reliable to solve the problem because when P > 4, the running time is quite long and the objective function value Z cannot be generated. In addition, because there is still dummy data, the results obtained are not able to represent the current problem situation. This is reflected in the absence of level variations at the chosen charging station.

If this model is applied, it will pose 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. Therefore, it is necessary to calculate and collect more systematic data, especially on the parameters of investment costs and service capacity so that the model can represent real conditions well and produce accurate objective function solutions. Another risk is that the government cannot anticipate queues and estimate the number of queues at the charging station. This is because the model does not consider scheduling and traffic congestion. Therefore, for further research, traffic density and maximum battery capacity and recharging duration need to be considered in order to predict the queues at the charging station.

4. Conclusion

The development of a supply chain network model for the charging station case in Surakarta has been carried out. The model has been run considering four scenarios and the selected candidate charging station locations and their levels have been identified. The model is able to provide suggestions to the government regarding solutions for the optimal location of the charging station construction. However, this model is not very reliable for solving problems and there are some risks if the model is applied. Therefore, the shortcomings and limitations of this model should 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. Thus, it is hoped that the model can provide more accurate and precise results and better represent real conditions.

References

Ahmad, A., Alam, M. S., Khan, Z., and Khateeb, S., A Review of the Electric Vehicle Charging Techniques, Standards, Progressions and Evolution of EV Technologies in Germany, *Smart Science,* vol. 6, pp. 36-53, 2018.

Aqidawati, E. F., Sutopo, W., and Hisjam, M., The integration of production-distribution on newspapers supply chain for cost minimization using analytic models: Case study, *IOP Conference Series: Materials Science and Engineering*, vol. 319, no. 1, p. 012075, 2018.

Aristyawati, N., Fahma, F., Sutopo, W., Purwanto, A., Nizam, M., Louhenapessy, B. B., and Mulyono, A. B., Designing framework for standardization and testing requirements for the secondary battery a case study of a lithium-ion battery module in an electric vehicle application, *2nd International Conference of Industrial, Mechanical, Electrical, and Chemical Engineering (ICIMECE),* Yogyakarta, Indonesia, October 6-7, 2016., pp. 207-212, 2016.

Atikah, N., Al Ghabid, A. H., Sutopo, W., Purwanto, A., and Nizam, M., Technical feasibility for technology commercialization of battery lithium-ion, *International Conference on Electrical Engineering and Computer Science (ICEECS)*, Bali, Indonesia, November 24-25, 2014, pp. 308-314, 2014.

Chen, C., and Hua, G., A new model for optimal deployment of electric vehicle charging and battery swapping stations, *International Journal of Control and Automation*, vol. 8, no. 5, 2014.

Cruz, F. O., Isaza, R. A. H., and Rendón, R. A. G., Optimal Location of Battery Swap Stations for Electric Vehicles, *Scientia et Technica*, vol. 24, no. 3, pp. 368-375, 2019.

Dericioglu, C., Yirik, E., Unal, E., Cuma, M. U., Onur, B., and Tumay, M., A Review of Charging Technologies for Commercial Electric Vehicles, *International Journal of Advances on Automotive and Technology*, vol. 2, pp. 61-70, 2018.

Fazeli, S. S., Venkatachalam, S., Chinnam, R. B., and Murat, A., Two-stage stochastic choice modeling approach for electric vehicle charging station network design in urban communities, *IEEE Transactions on Intelligent Transportation Systems*, 2020.

Giménez-Gaydou, D. A., Ribeiro, A. S., Gutiérrez, J., and Antunes, A. P., Optimal location of battery electric vehicle charging stations in urban areas: A new approach, *International Journal of Sustainable Transportation*, vol. 10, no. 5, pp. 393-405, 2016.

Huang, F. H., Exploring Information Needs of Using Battery Swapping System for Riders, *International Conference on Human Interface and the Management of Information,* pp. 531-541, 2016.

Jodinesa, M. N. A., Sutopo, W., and Zakaria, R., Markov chain analysis to identify the market share prediction of new technology: A case study of electric conversion motorcycle in Surakarta, Indonesia., *AIP Conference Proceedings*, vol. 2217, no. 1, p. 030062, 2020.

Karakitsios, I., Karfopoulus, E. L., and Hatziargyriou, N., Static and Dynamic Fast Inductive Charging: The Fastincharge Project Concept, *9th Mediterranean Conference on Power Generation, Transmission Distribution and Energy Conversion*, vol. 2014, pp. 1308-1314, 2014.

Kong, W., Luo, Y., Feng, G., Li, K., and Peng, H., Optimal location planning method of fast charging station for electric vehicles considering operators, drivers, vehicles, traffic flow and power grid, *Energy*, vol. 186, p. 115826, 2019.

Lu, X., Wang, P., Niyato, D., Kim, D. I., and Han, Z., Wireless Charging Technologies: Fundamentals, Standards, and Network Applications, *IEEE Communications Surveys and Tutorials*, vol. 18, pp. 1413-1452, 2016.

Lukic, S., and Pantic, Z., Cutting The Cord: Static and Dynamic Inductive Wireless Charging of Electric Vehicles, *IEEE Electrification Magazine*, vol. 1, pp. 57-64, 2013.

Lupita, A., Rangkuti, S. H., Sutopo, W., Hisjam, M., A supply chain model to improve the beef quality distribution using investment analysis: A case study, *AIP Conference Proceedings*, vol. 1902, no. 1, p. 020003, 2017.

Mak, H. Y., Rong, Y., and Shen, Z. J. M., Infrastructure planning for electric vehicles with battery swapping, *Management Science*, vol. 59, no. 7, pp. 1557-1575, 2013.

Martinez, J., Montoya, F. G., Montoya, M. G., and Manzano, F., Electric vehicles in Spain: An overview of charging systems, *Renewable and Sustainable Energy Reviews*, vol. 77, pp. 970-983, 2017.

Mehar, S., and Senouci, S. M., An optimization location scheme for electric charging stations, *International Conference on Smart Communications in Network Technologies (SaCoNeT),* Paris, France, June 17-19, 2013, vol. 1, pp. 1-5, 2013.

Nosi, C., Pucci, T., Silvestri, C., and Aquilani, B., Does Value Co-Creation Really Matter? An Investigation of Italian Millennials Intention to Buy Electric Cars, *Sustainability*, vol 9, pp. 1-21, 2017.

Prianjani, D., Fahma, F., Sutopo, W., Nizam, M., Purwanto, A., Louhenapessy, B. B., and Mulyono, A. B., The standard development for the National Standard of Indonesian (SNI) of the cell traction battery Lithium-ion Ferro phospate secondarry for electric vehicles applications, *2nd International Conference of Industrial, Mechanical, Electrical, and Chemical Engineering (ICIMECE)*, Yogyakarta, Indonesia, October 6-7, 2016 pp. 213-218, 2016.

Rahmawatie, B., Sutopo, W., Fahma, F., Purwanto, A., Nizam, M., Louhenapessy, B. B., and Mulyono, A. B., Designing framework for standardization and testing requirements of battery management system for electric vehicle application, *4th International Conference on Electric Vehicular Technology (ICEVT)*, Bali, Indonesia, October 2-5, 2017, pp. 7-12, 2017.

Sun, B., Sun, X., Tsang, D. H., and Whitt, W., Optimal battery purchasing and charging strategy at electric vehicle battery swap stations, *European Journal of Operational Research*, vol. 279, no. 2, pp. 524-539, 2019.

Sutopo, W., and Kadir, E. A., An Indonesian Standard of Lithium-ion Battery Cell Ferro Phosphate for Electric Vehicle Alications, *Telkomnika*, vol. 15, no. 2, pp. 584-589, 2017.

Sutopo, W., and Kadir, E. A., Designing Framework for Standardization Case Study: Lithium-Ion Battery Module in Electric Vehicle Application, *International Journal of Electrical and Computer Engineering*, vol. 8, no. 1, p. 220, 2018.

Sutopo, W., Hisjam, M., Yuniaristanto, Kurniawan, B., A goal programming approach for assessing the financial risk of corporate social responsibility programs in agri-food supply chain network, *Lecture Notes in Engineering and Computer Science 1 LNECS*, pp. 732-736, 2013.

Sutopo, W., Hisjam, M., Yuniaristanto, Kurniawan, B., Risk evaluation of the business performance of corporate social responsibility programs in Agri-food Supply Chain network, *IAENG Transactions on Engineering Sciences - Special Issue of the International MultiConference of Engineers and Computer Scientists*, *IMECS 2013 and World Congress on Engineering*, *WCE 2013*, pp. 175-181, 2014.

Sutopo, W., Maryanie, D. I., Purwanto, A., and Nizam, M., A comparative value chains analysis of battery technologies for electric vehicles, *Joint International Conference on Rural Information and Communication Technology and Electric-Vehicle Technology (rICT and ICeV-T),* Bandung, Indonesia, November 26-28, 2013, pp. 1-5, 2013.

Sutopo, W., Nizam, M., Rahmawatie, B., and Fahma, F., A Review of Electric Vehicles Charging Standard Development: Study Case in Indonesia, *5th International Conference on Electric Vehicular Technology (ICEVT)*, Surakarta, Indonesia, October 30-31, 2018, pp. 152-157, 2018.

Sutopo, W., Rahmawatie, B., Fahma, F., Nizam, M., Purwanto, A., Louhenapessy, B. B., and Kadir, E. A., A technical review of BMS performance standard for electric vehicle applications in Indonesia, *Telkomnika*, vol. 16, no. 2, pp. 544-549, 2018.

Wahyudin, R.S., Sutopo, W., Hisjam, M., Yuniaristanto, and Kurniawan, B. (2015), An agri-food supply chain model for cultivating the capabilities of farmers in accessing capital using corporate social responsibility program, *Proceedings of the International MultiConference of Engineers and Computer Scientists,* Hong Kong, March 18-20, 2015., vol. 2, pp. 877-882, 2015.

Waloyo, H. T., Nizam, M., and Saidi, H., Model-Based Simulation for Hybrid Fuel Cell/Battery/Ultracapacitor Electric Vehicle, *5th International Conference on Electric Vehicular Technology (ICEVT*), Surakarta, Indonesia, October 30-31, 2018, pp. 112-115, 2018.

Zeng, M., Pan, Y., Zhang, D., Lu, Z., and Li, Y., Data-Driven Location Selection for Battery Swapping Stations, *IEEE Access*, vol. 7, pp. 133760-133771, 2019.

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