

Model Development Framework for Determining Optimal Location and Investment Feasibility of Charging Station

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Abstract

The use of fossil fuels as a source of energy for vehicles is a serious problem, the high costs incurred for subsidies, fuel imports, and the impact on increasing environmental pollution emergencies need to be addressed by the government. This issue is an important issue regarding the sustainability of global energy to encourage efforts to reduce the use of fossil fuel products. Currently, the Indonesian government has planned an electric vehicle as a technology to replace fossil fuel vehicles. To support government programs, planning for charging station installations is one of the supporting aspects in terms of infrastructure that must be implemented. This charging station installation is the government's support for the people to be more confident in using electric vehicles because the installation costs will be higher if it is borne by individuals. As an innovation, charging station technology needs planning regarding the location of the installation and also the feasibility of investing in realizing it. Based on previous research, a supply chain network design model has been developed by considering the distance between the demand and the supply center (charging station). This study aims to propose a framework for developing an optimal location model for charging station installations and to produce a techno-economic analysis to measure the investment feasibility of the chosen charging station to be installed. The performance framework for developing the model generated from this study is expected to provide insight and input to several stakeholders as an option in developing a supply chain model for charging station installation locations and techno-economic analysis in planning project business for the general public.

Keywords

Charging station, optimal location, economic feasibility, feasibility investment

1. Introduction

In modern times like today, the need for transportation is one of the important needs as a result of economic, social, and so on, which demands a rapid increase in population mobility and other resources. In recent years there have been many developments in public transportation used by the community, from motorized pedicabs to private vehicles with the concept of sharing. It takes a lot of time and money to create a quality transportation system. Transportation is one sector that contributes a lot to the amount of CO₂ levels in the air. The number of vehicles currently operating are

those that use fossil fuel energy sources. This fuel has several negative impacts that can be felt directly or indirectly, including the increase in the state budget allocation for fuel subsidies, energy sustainability, and high levels of carbon (CO₂) emissions. According to the European Environment Agency (2010), the transportation sector is one of the largest contributors to carbon gas emissions in the world. This is because there are still many uses of vehicles using fossil fuels. One of the most widely used transportation in Indonesia is a motorcycle. The number of motorbikes in Indonesia reached 120 million units in 2018 (Badan Pusat Statistik, 2019). Handling that can be done is a technological innovation that can reduce energy use in Indonesia. The most influential technological innovation from the transportation sector is the use of fuel with alternative energy sources, this can certainly reduce high levels of CO₂ and the use of fossil energy. One thing that can be used to reduce this is by electrifying motorbikes (Ahmad et al., 2018). By implementing green logistics through the use of electric vehicles in Indonesia such as hybrid electric vehicles, plug-in hybrid electric vehicles, and battery electric vehicles (Samosir, et al. 2018). Electric vehicle technology innovation and battery technology innovation can provide environmentally-friendly transportation solutions, energy-efficient, and lower operating and maintenance costs (Sutopo, et al. 2013). The government plans to switch from fossil-fueled vehicles to electric-fueled vehicles, this shows that the country is preparing to accelerate the transition of electric vehicles (Kusumo, 2017). Government through Presidential Regulation No. 55 of 2019 concerning the Acceleration of the Battery Electric Vehicle Program for Road Transportation also encourages the electrification process of these vehicles. Several studies have discussed convertible motorbikes, Habibie and Sutopo (2019) explain that conversion electric motorbikes are considered more effective because they can directly reduce conventional motorbikes that are converted to convertible electric motorbikes and have a direct impact on carbon reduction. In terms of electric motorbike conversion technology, a prototype has been made and technology adoption can be carried out (Utami et al., 2020).

The Australian state predicts that the most widely used transportation technology in the future is an electric vehicle or zero-emission vehicle (ZEV) (Ameli & Kammen, 2012). The EV is driven by a battery-powered motor, which the battery can be charged by connecting the vehicle to the power grid either at home or at a public charging station (Ahmadi, et al., 2015). The importance of electric vehicle technology innovation to provide transportation solutions that are environmentally friendly, energy-efficient, and cheaper to operate and maintain (Sutopo, et al., 2013). The development of electric vehicles in Indonesia is believed to be larger in the future. This development requires support in planning and implementation, to obtain optimal results in its operation. Jodinesa, et al (2020) identified the market share of convertible electric motorbikes in Surakarta City and concluded that the people of Surakarta City gave a positive response to the development of convertible electric motorbikes. From this research, it can be explained that the opportunity for electric motorbikes is quite large. Electric vehicle innovation also encourages the birth of new entities in the electric vehicle supply chain, including technopreneurs and start-ups from developers, suppliers, manufacturers, and distributors of electric vehicle products/services and their derivatives to the market (Yunaristanto, et al. 2014).

Utami, et al (2020) have researched consumer perceptions of electric vehicles in Surakarta, the study explains that the purchase price, model, vehicle performance, and infrastructure readiness are the biggest obstacles for people to adopt electric vehicles. Therefore, a planning model is needed so that this electric motorbike becomes a business plan that can be implemented to realize the government's plan to reduce carbon emissions. The required infrastructure planning regarding the location for the electric refueling terminal is optimal for coverage of existing demand. This will have a major impact on the planning for the construction of electric refueling terminals, distribution lines, community activity lines, and also the development of city infrastructure. Istiqomah, et al (2020) have planned a charging station allocation by considering the distance of consumers to the charging station to be built. This approach is taken to assist planning authorities and make policies in making decisions related to the Electric Vehicle sector. Strategic supply chain network design is considered one of the most important stages, which has a significant effect on all future strategies at the tactical and operational levels (Farahani, et al. 2013). Supply chain network design (SCND) decisions have a significant effect on supply chain (SC) performance because they affect total inventory and transportation costs in the long run. In determining the opening of facilities, one of the things that must be considered is the economies of scale (Watson, et al. 2013). An efficient distribution allocation location system will be able to minimize transportation costs (Pujawan & Mahendrawathi, 2017).

Location planning with a model needs to be done to get the optimal location for the charging station installation. this helps the government as a stakeholder to make decisions for technological developments that will be built in their city. Besides the feasibility of a charging station to be installed can be analyzed using techno-economic analysis by considering the costs and benefits of implementing standards. Besides techno-economic analysis is needed to

harmonize investment calculations for the budget estimate prepared for installing a charging station. Thus, the charging station allocation model and investment feasibility are expected to provide significant benefits for the city government. This study aims to produce a model development framework for determining the location of charging station installations and a techno-economic analysis to measure the investment feasibility of a charging station installation to be carried out.

2. Literature Review

With the government's desire to convert vehicles into electric vehicles. Several state companies have made studies regarding various charging stations that will be launched later. Private companies will operate and PLN will supply electricity through its partnership scheme, partnership operation. Improving the charging infrastructure system is the key to the large-scale implementation of electric vehicles (Hatto et al, 2009; Sweda & Klabjan, 2011). Liu & Wang (2017) explain a modeling framework for positioning multi-type BEV charging facilities is proposed to minimize public social costs and meet the demands of different types of BEV. Tu et al. (2016) modeled the interaction between demands for electric taxis, electric taxis, and charging stations. To optimize charging stations, some studies have also begun to focus on the location and size of charging stations (Davidov & Pantos, 2017), The layout of charging stations for electric vehicles is a problem of location optimization, and many studies have revealed the optimal location of charging stations (Lou et al, 2018; Dominguez-Navarro et al, 2019). Ge et al. (2018) proposed a dynamic traffic simulation-based optimization planning technology for an EV charging station in an expressway network, aiming at the problem that the existing research could not consider the travel demand of vehicle space and time change. According to the historical data of EV parking behavior, the specific charging demand corresponding to each charging behavior is predicted, and the prediction method is essentially a Monte Carlo simulation method (Zhang et al, 2014). Cauwer et al. (2015) developed a model to estimate an electric vehicle's power consumption using the kinematic parameters of the electric vehicle (EV) or the trip data as inputs.

The method used for location division is the centrality index. This area will be divided into different levels based on the crowd and the availability of public facilities. Newman (2006) explains that the modularity matrix can detect communities similar to those played by the graph, it can represent the condition of the area. Fan et al (2019) found that most centers and one particular sub-center have a high assessment index, moving towards good environmental cohesiveness and accessibility. Yan et al (2018) use a degree of centrality index to reconstruct the initialization region sequence.

3. A Framework SCND for Charging Station Installation

The planning framework for the charging station installation location is quite important to support the acceleration of the commercialization of electric vehicles. Apart from that, the multiplication of charging stations needs to be done to provide input to the city government, this is done so that the government can provide good services to the community.

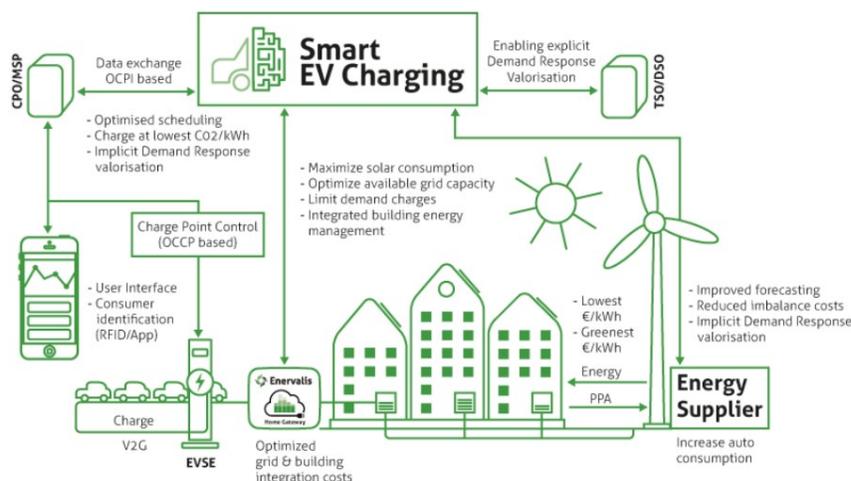


Figure 1. Problem Conditions in The System
 (Source: <https://www.enervalis.com/smart-ev-charging/> , 2021)

The planning conditions for charging station development have been described in Figure 1. Figure 1 explains the advantages and impacts of using a charging station to meet the growing needs of electric vehicles. The number of benefits obtained is expected to be a positive aspect that is provided by the government to the community. Carbon emissions generated by community activities can also be reduced quite a lot so that environmental conditions remain good, this has a reciprocal impact on the government and also the community itself in terms of the environment that can be shared.

3.1 Model Supply Chain for Installing Charging Station

From the research framework that will be carried out, several stakeholders who will be involved in this planning come from various parties. The city government as a stakeholder in planning the readiness of the city to accept technological developments that will be developed in its area, charging station manufacturing companies that will later supply certain types of charging stations that have been selected to be installed in the region, and power companies that provide the availability of power to be distributed to the area. electric vehicle. From the framework in Figure 2, it is explained that the construction sites will be planned in public facilities such as malls, markets, hospitals, office areas, educational areas, and several other public locations.

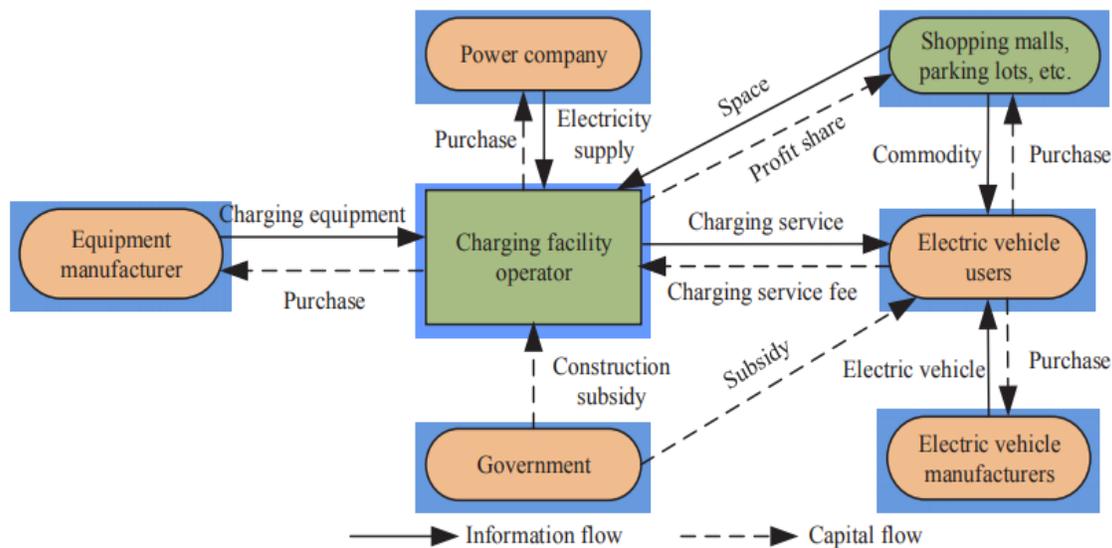


Figure 2. Outline of The Charging Station Installation Business Model

With the business model that has been described, Figure 3 describe that the steps taken to identify variables and determine the location are carried out to support location selection decisions. Besides the model that will be developed later can identify the need for charging stations in an area. The first component of the research phase is identifying the regional systems and infrastructure that are the object of the study, then the influencing variables will be identified to support the decisions produced by the model. From the modeling, perform a techno-economic analysis of the type of charging station that can be implemented. From the results of this analysis, it will produce suggestions that can be reviewed by several stakeholders as a reference basis for realizing the government's plan to commercialize electric vehicles by procuring supporting infrastructure, namely charging stations.

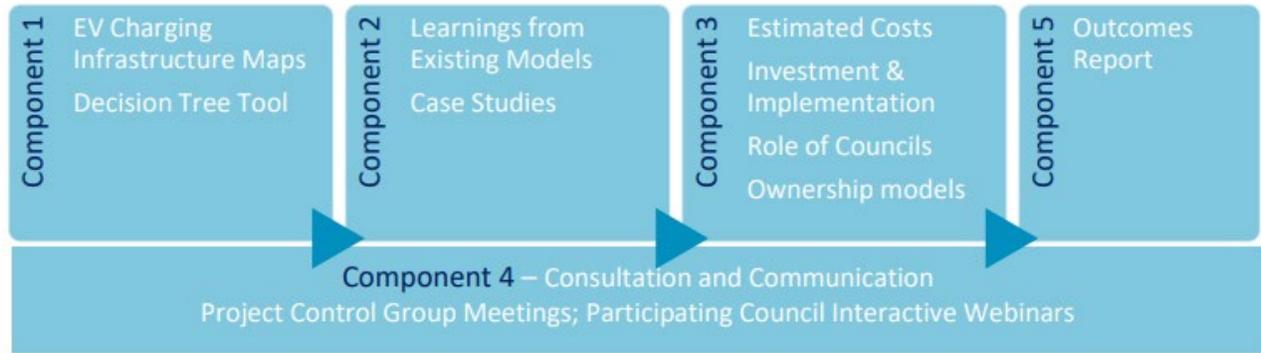


Figure 3. The Design of Research Stages

Within the framework of developing this model, several parameters (Table 1) are obtained which will need to be used to obtain a standard model in determining the location of the charging station installation. This parameter can be developed with different decision variables. This parameter is a general parameter that can be extended under various conditions.

Table 1. Parameters used in the study

Parameter	Information	Parameter	Information
A_j	Cost of building a charging station at the node j .	k_j^{sc}	Percentage of filling services provided by the supercharger at node j .
B_{ij}	The total time spent at node j is satisfied by the load requests from area i .	k_j^{dc}	Percentage of charging services provided by destination-chargers at node j .
n	The number of areas with demands on fees.	T^{sc}	The time it takes for the supercharger to charge the EV.
m	Number of candidate filling stations	T^{dc}	The time it takes for the destination charger to charge the EV.
c^{sc}	The cost of building a supercharger.	p^{sc}	The number of EVs the supercharger can charge in one day.
c^{dc}	The cost of building a destination charger.	p^{dc}	The number of EVs the destination charger can charge in one day.
n_i^{ev}	Total number of EVs that have charging requirements in the area i .	n_p^i	Residents i .
d_{ij}	Distance between area i and station	d^{day}	Daily average EV distance.
\bar{v}	Average EV driving speed in the city.	d^{full}	The distance that a fully loaded electric vehicle can cover.
ρ	Current vehicle to population ratio.	β	The proportion of charging needs met by home chargers.
z_j	Decision variable, if build a charging station at node j	n_j^{sc}	Number of superchargers built at node j
Q_{ij}	Decision variable, if charging needs in i is satisfied at node j	n_j^{dc}	Number of destination-chargers built at node j
F_{ij}	The cost of carbon tax		

$$\min C = \sum_{j \in J} \sum_{i \in I} n_i^{ev} F_{ij} + \sum_{j=0}^m z_j A_j + \lambda \sum_{i=0}^n \sum_{j=0}^m Q_{ij} B_{ij} \quad (1)$$

$$z_j \in \{0, 1\} \quad (2)$$

$$Q_{ij} \in \{0, 1\} \quad (3)$$

$$z_j \geq Q_{ij} \quad (4)$$

$$n_j^{sc}, n_j^{dc} \in R \quad (5)$$

$$z_j (P^{sc} n_j^{sc} + P^{dc} n_j^{dc}) \geq \sum_{i=0}^n Q_{ij} n_i^{ev} \quad (6)$$

$$\sum_{j=0}^m Q_{ij} = 1 \quad (7)$$

Note

$$A_j = c^{sc} n_j^{sc} + c^{dc} n_j^{dc} \quad (8)$$

$$B_{ij} = n_i^{ev} \left(\frac{d_{ij}}{v} + k_j^{sc} T^{sc} + k_j^{dc} T^{dc} \right) \quad (9)$$

3.2 Economic Benefits Assessment Parameters

The second instrument is various library sources as well as discussions with experts regarding charging stations to determine the costs that will be used and also the advantages of installing charging stations in an area. These costs will be analyzed using the net present value and B / C Ratio methods to determine the investment feasibility of the charging station installation. Figure 4 explain some aspects about the cost and benefit from this project.

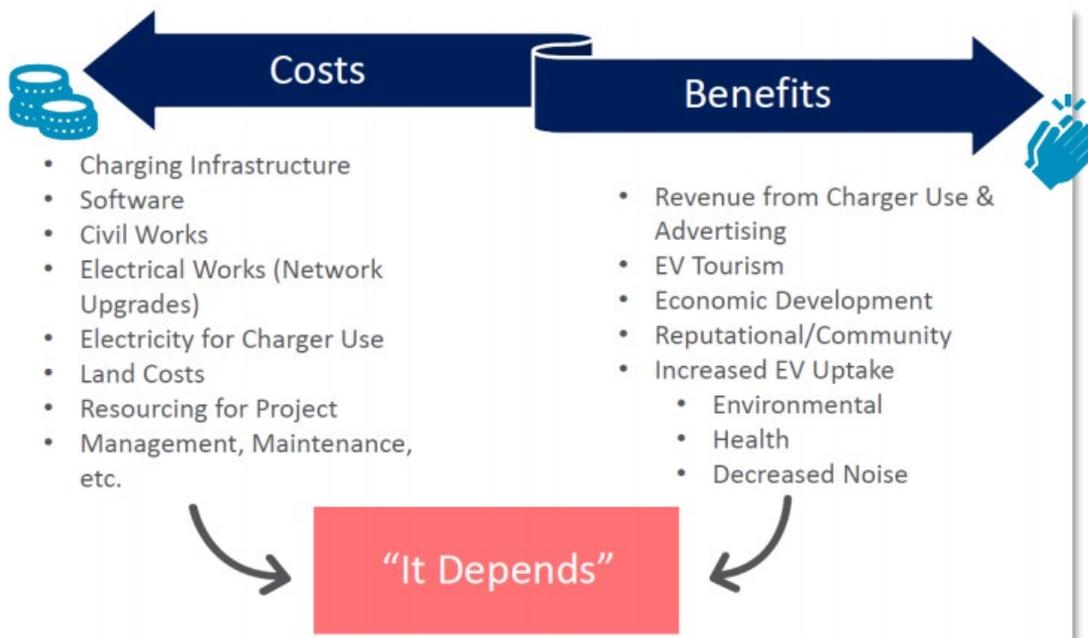


Figure 4. Cost and Benefits costs of Procuring a Charging Station

Net present value contributes to the time value of money which makes it a better approach than investment valuation techniques that do not discount future cash flows such as a period of returns and accounting returns. This model uses the NPV because this method will assess the NPV of the project to be executed. The results of this NPV will show whether or not the investment can be carried out, related to the company's future profits and losses. This method can assist the government in planning projects with a fairly long period, the usefulness of the charging station installation will also be more positive over time. Besides the B / C Ratio method is also used in determining the investment feasibility of charging station inflation. The benefit-Cost Ratio is a method of investment feasibility. The calculation of this investment feasibility method emphasizes the benefits and sacrifices of an investment.

4. Conclusion

A research framework has been designed to develop a model for determining the optimal location and economic viability of a charging station installation. The model developed aims to determine the optimal location for the installation of a charging station, this location will cover several things, including the range of demand served and optimal power consumption. Apart from this model, this framework also uses techno-economic analysis to determine the type of charging station to be installed on the system. This model integrates a mathematical model approach and also the calculation of investment feasibility. This model can be used as a reference and basis for stakeholders who will conduct similar research. From the calculation of the centrality index, the determination of the area with community activities can be detected. In addition, this study can provide an overview of the framework of the development of a model to determine the location and techno-economic calculations of the public facilities to be built. Based on the results of the techno-economic analysis, this study can provide recommendations to the city government regarding aspects that will be affected by the construction of these public facilities. Further research can be carried out to test the model by providing the results of its analysis data processing.

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