Development of Location-Allocation Model of Network Design for Battery Swapping Station and Battery Charging Station Facilities for E-Trike and E-Motorcycle

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Abstract

Electric vehicles have been shown to lessen air pollution caused by transportation. However, because the number of motorcycle riders in Indonesia is fairly big, and because becak was once a major mode of transportation in Indonesia, the usage of electric vehicles such as e-motorcycles and e-trikes is an interesting object to develop. A good establishment of battery recharging facilities can accelerate the use of electric vehicles. Hence, planning for the establishment of a network of battery recharging facilities needs to be done. This study proposes a network design model for the battery charging station and battery swapping station facilities in Surakarta City to achieve maximum coverage with minimum cost. Market and mall locations in Surakarta City are potential locations to be chosen as battery charging stations and battery swapping stations. The MILP model is run using LINGO to reach the optimal solution. The results of this study succeeded in determining the location of the battery charging station and the battery swapping station in markets and malls in Surakarta with an investment feasibility study. This research is expected to provide input to Solo Technopark and the Surakarta Government in accelerating the use of electric vehicles.

Keywords
Battery Swapping Station, Battery Charging Station, Electric Vehicle, Facility Location, Location-allocation.

1. Introduction
Cars, trucks, airplanes, ships, and other vehicles account for roughly 15% of all man-made carbon dioxide. As a result, one of the most crucial strategies in fighting global warming is to reduce transportation emissions. (Chen et al. 2018). The adoption of alternative fuel cars is becoming increasingly significant as a result of worries about climate change, energy security, urban air pollution, and the growing demand for sustainable transportation services (Melaina and Bremson 2008). Electric vehicles (EVs) with batteries can be charged using standard electrical outlets and have lower

running expenses than cars with combustion engines. They're also efficient, don't pollute the environment, and are practically silent. (Eggers and Eggers 2011). Electric vehicles (EVs) are currently being widely used because they can reduce the number of fossil fuels and greenhouse gas emissions. However, there are still many people who buy and use vehicles with an Internal Combustion Engine (ICE) because they are afraid and worried about several things when using electric vehicles, such as long charging times, short battery life, limited mileage each charging, and price. expensive electric vehicle batteries (Wu et al. 2017).

The problem raised in this study is that STP as a producer will provide battery recharging facilities for the use of e-trikes and e-motorcycles, but the location and amount that must be provided to cover all demands has not been determined. In the research of Nugrahadi et al. (2021), modeling was carried out to determine the location-allocation of charging stations by considering the investment costs. Nugrahadi et al. (2021) only considered the establish of battery charging station (BCS) systems. When only one type of battery recharge system is used at a station, that station will only be used on a limited basis (Chen et al. 2018). Recharging by charging can take a lot of time even at sophisticated charging stations. Recharging electric vehicles must at least have the same user experience as charging at a gas station. The battery swap system can solve the problem of long battery charging. On the other hand, one of the advantages of a battery swapping station is that an empty battery that is replaced can be charged when electricity is at a low cost. By controlling the filling time, the potential for demand spikes during peak times can be overcome, thereby balancing supply and demand. The battery swap system is also capable of charging the battery using a lower voltage than fast charging, thereby extending battery life (Sun et al. 2019). Battery swapping stations are also able to overcome concerns about vehicle mileage, length of recharging time, expensive battery prices, and short battery life because battery swapping stations can provide fully charged batteries easily and quickly (Wu et al. 2017). Based on research from (You and Hsieh, 2014), the key to consider in planning the manufacture of battery recharging stations is the number, location, and type of charging station. Therefore, the formulation of the research problem is the development of a model to determine the location and allocation of two types of charging stations, namely battery swapping station (BSS) systems and battery charging station (BCS) by considering the investment costs.

The purpose of this study is to develop a model for determining the location-allocation of battery swapping station (BSS) and battery charging station (BCS) to cover the maximum area and minimize cost. The development of this optimization model has the objective of minimizing the total cost which includes the initial investment, total fixed costs, total variable costs, and total transportation costs. It also aims to maximize the total number of customers served. Key decisions in the proposed research are the amount of allocation, location, and type of battery swapping station (BSS) systems or battery charging station (BCS) as well as the feasibility of the investment. The location of each type of charging station facility is placed according to the area and cost of the place. For investment feasibility, each investment feasibility indicator such as Break-Even Points (BEP), Net Present Value (NPV), Return on Investment (ROI), and Payback period analysis (PP) must obtain results that can determine whether the charging station investment can be carried out or not.

2. Literature Review

The supply chain is described as a series of companies, suppliers, customers, and/or other entities that are directly involved in the upstream and downstream flows of products, services, financing, and/or information from suppliers to customers. (Mentzer et al. 2001). Supply chain network design is one of the most important, major, and strategic decisions affecting competitive advantage and all other decisions in supply chain management (Hajiaghaei-Keshteli and Fard 2019). Suppliers, manufacturers, warehouses, and the movement of items from each product origin to the final customer define the supply chain. The quantity and location of these facilities are important determinants in any supply chain's performance. According to some estimates, 80 percent of supply chain costs are determined by facility location and optimal product flow. (Watson et al. 2013).

In general, the problem of location-allocation usually pays attention to several aspects such as minimizing impedance (P-Medium), maximizing market share, minimizing the number of facilities, maximizing coverage, and focusing on targeting a specific market share (Chen et al. 2018). For emergency facility location problems, the set coverage model is the most often used location model. The goal of this model is to figure out how many service facilities are needed to cover all demands (Zhang et al. 2017). The maximal covering location problem is an extension of the set covering model (MCLP). This strategy is typically used to position a number of facilities in a way that maximizes existing demand (Zhang et al. 2017).

An analysis of the feasibility of investing in a supply chain activity needs to be done to find out whether the investment made is economically feasible. The analytical methods that are often used to calculate the parameters to determine investment feasibility are Return on Investment (ROI), Net Present Value (NPV), BEP, PP. The number of assets used by the company or a measure of managerial efficiency determines the Return on Investment. The difference between the present value of cash inflows and the present value of cash outflows in a given period is the Net Present Value. The break-even point, on the other hand, is the number of items or services that must be sold each period for the company's operating activities to remain profitable. Furthermore, the payback period is the amount of time it takes to repay the value of the investment (Marsiwi et al. 2019).

A study by Nugrahadi et al. (2021) has developed a model for determining the location and allocation of charging station facilities, especially for e-trike. This case study conducted in the city of Surakarta also considers the feasibility of investing in a charging station as an assistant in supplier decisions. An investment feasibility analysis was carried out using the Break-even Points (BEP), Net Present Value (NPV), Return on Investment (ROI) methods, and Payback period analysis (PP). The mathematical model has the objective function of minimizing the total cost consisting of investment costs, fixed costs, variable costs, and transportation costs. Chen et al. (2018) conducted a study to determine the optimal location for e-scooters vehicles. In this study, the location determination considers two types of recharging facilities, namely battery swapping station (BSS) systems, and battery charging station (BCS) systems. This study has a MILP mathematical model with the objective function of minimizing costs and maximizing cover rates. Wang and Lin (2013) conducted a study on determining the location of recharging stations by experimenting with the establishment of a mixed station and one type of battery recharging station. The research models the minimization of the total cost of placing various types of recharging electric vehicle batteries to maximize coverage. Therefore, in this paper, model development is conducted not only to decide the location-allocation of two types of recharging stations but also to consider the investment feasibility.

3. Methods

This paper focuses on the location and the allocation of a battery swapping station (BSS) and a battery charging station (BCS) for e-trike and e-motorcycle with maximizing area coverage and evaluating the investment feasibility. Supply chain planning is needed because the design to be implemented must consider the location, distribution of consumers, and the costs that must be incurred. This will create optimal results for the stakeholders involved, several things considered will help the model to achieve optimal results.

In this study, several supply chain activities occur.

1. Solo Technopark as a manufacturer and supplier plays a role in providing charging station facilities. Solo Technopark acts to determine the type and specifications of the CS, and apply the cost per kWh.

2. Traditional markets and malls located in Surakarta are potential locations for the establishment of charging station facilities. Charging station facilities are built at each potential location and then the location can be accessed by people who need recharging station facilities.

3. E-trike and e-motorcycle users are the consumers of battery recharging facilities in this research. Becak drivers who want to switch to using electric vehicles in Surakarta provide e-trike services and receive e-trike service orders, also receive tariffs according to the distance traveled.

Based on the problem formulation, it can be determined the data needed for planning the location of the battery recharging station in Surakarta. The demand for charging stations is assumed to be the same as the demand for e-motorcycles, which refers to the market share prediction from the research of Jodinesa et al. (2020) and based on data from the Minister of Energy and Mineral Resources Regulation Number 13 of 2020 concerning Provision of Electric Charging Infrastructure for Battery-Based Electric Motor Vehicles. Furthermore, the coordinates and the distance between locations of traditional markets and malls in Surakarta were obtained from the research of Nugrahadi et al. (2021).

The first step in developing the model is to describe the problem to identify the entities, activities, and variables involved. Next, a literature review was conducted to find a reference model that fits the problem. The next step is to adjust the notation as well as the reference model variables to become one suitable model. After that, make an influence diagram based on the problem formulation that has been made so that it can find out the relationship between variables, as shown in Figure 1. In the last step, the model is combined by paying attention to the influence diagram to obtain a mathematical model formulation.

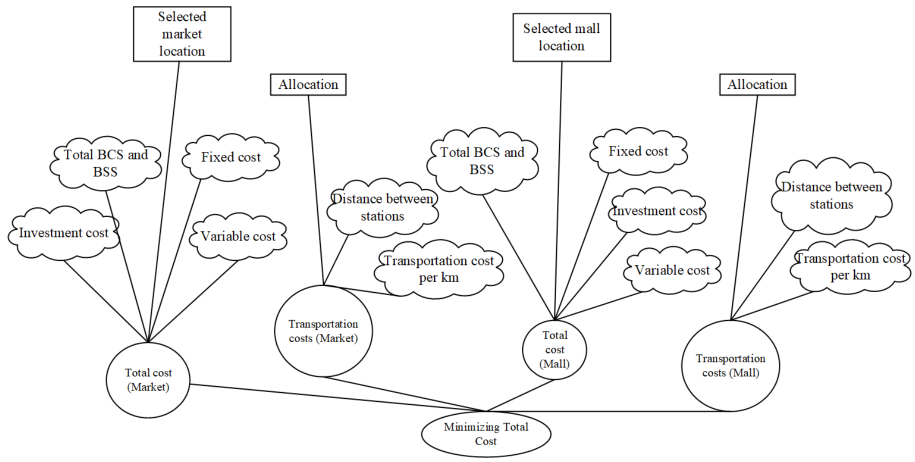

Figure 1. Influence Diagram

The following is a description of each notation.

i	: market source
j	: destination from market
m	: mall source
n	: destination from a mall
$trans_{ij}$	: distance between source *i* to destination *j*
$trans_{mn}$	: distance between source *m* to destination *n*
D_i	: demand in location *i*
D_m	: demand in location *m*
Q_i	: transportation cost in location *i*
H_m	: transportation cost in location *m*
$dist_{ij}$	: allocation from source *i* to destination *j*
$dist_{mn}$	: allocation from source *m* to destination *n*
$ICMarketCS$	: initial investment of battery charging station in the market
$ICMarketBSS$	: initial investment of battery swapping station in the market
$ICMallCS$	: initial investment of battery charging station in the mall
$ICMallBSS$	: initial investment of battery swapping station in the mall
$FCMarketCS$	: fixed cost battery charging station at the market
$FCMarketBSS$	: fixed cost battery swapping station at the market
$FCMallCS$	: fixed cost battery charging station at the mall
$FCMallBSS$	: fixed cost battery swapping station at the mall
$VCMarketCS$	: variable cost charging station at the market
$VCMarketBSS$	: variable cost of battery swapping station at the market
$VCMallCS$	: variable cost of charging station at the mall
$VCMallBSS$	: variable cost of battery swapping station in the mall
$Lmax$	: maximum number of locations to be built
$Lmin$	: minimum number of locations to be built
$Bmin$	: minimum number of locations where battery swapping station will be built
$CmarketCS$	: battery charging station capacity at the market
$CmarketBSS$	: battery swapping station capacity at the market
$CmallCS$	: charging station capacity at the mall
$CmallBSS$	: battery swapping station capacity at the mall

ORP_i : $\begin{cases} 1, \text{if market location } i \text{ is chosen, charging station will be built} \\ 0, \text{not selected} \end{cases}$

OBP_i : $\begin{cases} 1, \text{if market location } i \text{ is chosen, battery swapping station will be built} \\ 0, \text{not selected} \end{cases}$

ORP_m : $\begin{cases} 1, \text{if mall location } i \text{ is chosen, charging station will be built} \\ 0, \text{not selected} \end{cases}$

OBP_m : $\begin{cases} 1, \text{if mall location } m \text{ is chosen, battery swapping station will be built} \\ 0, \text{not selected} \end{cases}$

$dist_{ij}$: $\begin{cases} 1, \text{if source } i \text{ is served at location } j \\ 0, \text{no} \end{cases}$

$dist_{mn}$: $\begin{cases} 1, \text{if source } m \text{ is served at location } n \\ 0, \text{no} \end{cases}$

The objective function is formulated as follows.

$$\begin{aligned} Z = Min[&\textstyle\sum_{i\in I} ICMarketCS_i ORP_i + \sum_{i\in I} FCMarketCS_i ORP_i + \sum_{i\in I} VCMarketCS_i ORP_i + \\ &\textstyle\sum_{i\in I}\sum_{j\in J} Q_i\, trans_{ij} dist_{ij}] + [\sum_{m\in M} ICMallCS_m ORM_m + \sum_{m\in M} FCMallCS_m ORM_m + \\ &\textstyle\sum_{m\in M} VCMallCS_m ORM_m + \sum_{m\in M}\sum_{n\in N} H_m\, trans_{mn} dist_{mn}] + \sum_{i\in I} ICMarketBSS_i OBP_i + \\ &\textstyle\sum_{i\in I} FCMarketBSS_i OBP_i + \sum_{i\in I} VCMarketBSS_i OBP_i + \sum_{i\in I}\sum_{j\in J} Q_i\, trans_{ij} dist_{ij}] + \\ &\textstyle[\sum_{m\in M} ICMallBSS_m OBM_m + \sum_{m\in M} FCMallBSS_m OBM_m + \sum_{m\in M} VCMallCS_m OBM_m + \\ &\textstyle\sum_{m\in M}\sum_{n\in N} H_m\, trans_{mn} dist_{mn}] \end{aligned} \quad (1)$$

Then the limitations are formulated as follows.

$$\textstyle\sum_i ORP_i + \sum_i OBP_i + \sum_m ORP_m + \sum_m OBP_m \le Lmax \qquad \forall i \in I, \forall m \in M \quad (2)$$
$$\textstyle\sum_i ORP_i + \sum_i OBP_i + \sum_m ORP_m + \sum_m OBP_m \ge Lmin \qquad \forall i \in I, \forall m \in M \quad (3)$$
$$\textstyle\sum_i OBP_i + \sum_m OBP_m \ge Bmin \qquad \forall i \in I, \forall m \in M \quad (4)$$
$$\textstyle\sum_j dist_{ij} \ge 1 \qquad \forall i \in I, \forall j \in J \quad (5)$$
$$\textstyle\sum_m dist_{mn} \ge 1 \qquad \forall m \in M, \forall n \in N \quad (6)$$
$$\textstyle\sum_i D_i dist_{ij} \le \sum_i CmarketORP_i + \sum_i CmarketOBP_i + \sum_m CmallORP_m + \sum_i CmallOBP_m \qquad \forall i \in I, \forall j \in J, \forall m \in M, \forall n \in N \quad (7)$$
$$\textstyle\sum_m D_m dist_{mn} \le \sum_i CmarketORP_i + \sum_i CmarketOBP_i + \sum_m CmallORP_m + \sum_i CmallOBP_m \qquad \forall i \in I, \forall j \in J, \forall m \in M, \forall n \in N \quad (8)$$
$$ORP_i \in \{0,1\} \qquad \forall i \in I \quad (9)$$
$$OBP_i \in \{0,1\} \qquad \forall i \in I \quad (10)$$
$$ORP_m \in \{0,1\} \qquad \forall m \in M \quad (11)$$
$$OBP_m \in \{0,1\} \qquad \forall m \in M \quad (12)$$
$$dist_{ij} \in \{0,1\} \qquad \forall i \in I, \forall j \in J \quad (13)$$
$$dist_{mn} \in \{0,1\} \qquad \forall m \in M, \forall n \in N \quad (14)$$

The objective function (1) of this mathematical model is to optimize the total cost to get the minimum result. Equations (2) and (3) show that each location for charging stations and battery swapping stations in markets and malls to be built is no more or less than the number limit. Equation (4) shows that the battery swapping station facility to be built in a mall or market is not less than the *Bmin* value. Equations (5) and (6) show that consumers can be served by at least one charging station or battery swapping station. Equations (7) and (8) show that the number of requests served by the facility does not exceed the capacity of the charging station and battery swapping station facilities. Equations (9), (10), (11), and (12) show the binary number of the selected location or not to build a charging station or battery swapping station. Equations (13), and (14) show binary numbers if consumers from the source are served at the charging station or battery swapping station.

4. Data Collection

In this study, traditional markets and malls in Surakarta are potential locations for placing battery recharging stations. According to Nugrahadi et al. (2021), there are 42 traditional markets and 3 malls in Surakarta which have the potential to become locations for battery swapping stations and charging stations. The supply chain network design in this study can be presented in Figure 2 as follows.

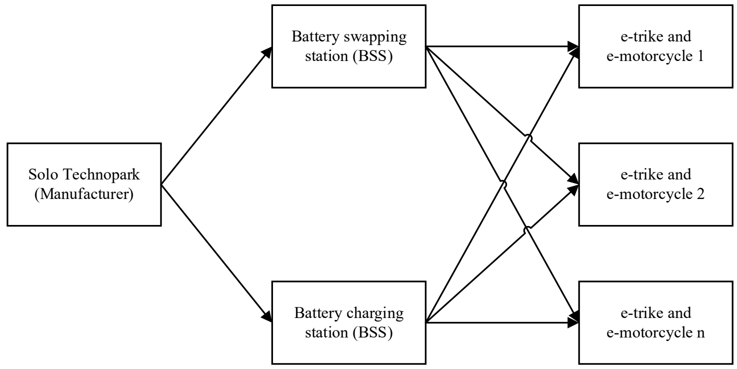

Figure 2. Battery swapping and charging station supply chain network design

Table 1. Potential locations for building battery swapping stations and charging stations

Location	Symbol	Location	Symbol	Location	Symbol
Elpabes Market	X1	Notoharjo Market	X16	Solo Grand Mall	X31
Sidomulyo Market	X2	Kliwon Market	X17	Harjodaksino Market	X32
Triwindu Market	X3	Joglo Market	X18	Singosaren Market	X33
Nongko Market	X4	Gading Market	X19	Tanggul Market	X34
Ngumbul Market	X5	Cinderamata Market	X20	Rejosari Market	X35
Ngarsopuro Market	X6	Besi Tua Market	X21	Pucangsawit Market	X36
Legi Market	X7	Ayam Market	X22	Panggungrejo Market	X37
Depok Market	X8	Sidodadi Market	X23	Nusukan Market	X38
Bangunharjo Market	X9	Purwosari Market	X24	Ngudi Rejeki Gilingan Market	X39
Bambu Market	X10	Penumping Market	X25	Ngemplak Market	X40
Ayu Balapan Market	X11	Kembang Market	X26	Mojosongo Market	X41
Meubel Market	X12	Kadipolo Market	X27	Ledoksari Market	X42
Solo Paragaon Mall	X13	Kabangan Market	X28	Jurug Market	X43
Tunggul Sari Market	X14	Jongke Market	X29	Jebres Market	X44
Sangkrah Market	X15	Solo Square	X30	Gede Market	X45

The location candidate to build the recharging station in Table 1. need to be re-selected based on their ability to meet the requirements for building a battery recharging station. According to Nugrahadi et al. (2021), the requirements include the location must have a permanent physical building, have a minimum electrical power of 7000 VA, and have a parking space. The potential locations of traditional markets and malls are X1, X3, X4, X6, X7, X8, X9, X11, X13, X15, X16, X17, X19, X20, X23, X24, X26, X27, X29, X30, X31, X32, X33, X35, X36, X37, X38, X39, X40, X41, X42, X44, X45.

There are several types of battery charging stations based on their power and their number of plugs. In this study, a fast-charging station with multiple plugs and powered ≤ 50 kWh. This charging station cost IDR 729,000,000. Based on the Regulation of the Minister of ESDM Number 13 of 2020 Concerning Provision of Electricity Charging Infrastructure for Battery-Based Electric Motor Vehicles, the electricity price per kWh is IDR 1,650. On the other hand, the battery swapping station costs IDR 406,728,000 excluding the batteries. 60 batteries costs for IDR 337,440,000. Therefore, the total of setting up only a battery swapping station is IDR 744,168,000, excluding land cost and electricity installation cost. Some assumptions were employed in the investment calculations in this study. The conventional market is expected to operate for 10 hours per day, while the mall will operate for 12 hours. Electricity costs IDR 566 per kWh, with a selling price of IDR 1,650 per kWh. The discount rate used in this study to generate the investment feasibility indicator is 10%, with a 20-year economic life or periods.

5. Results and Discussion

1. Investment from the establishment of a battery charging station in the traditional market

Table 2. Battery charging station initial investment in the traditional market

No	Item	Total	Unit	Price (IDR)	Investment (IDR)	Economic Life (year)
1	Construction cost	6	m^2	2,000,000	12,000,000	20
2	Electrical installation	1		7,500,000	7,500,000	20
3	Charging station fast charging type	2	unit	729,000,000	458,000,000	20
Total					1,477,500,000	

In addition to the initial investment shown in Table 2, the investment feasibility study must account for fixed costs. Maintenance costs, overhead, labor, and land rent are fixed annual costs to build a battery charging station in a traditional market with a total of IDR 27,180,000. The investment calculation for battery charging stations on the market assumes that 80 units of e-trike and e-motorcycle will be charged every day. As a result, the yearly service capacity can reach 28,800 units, with an annual energy demand of 77,760 kWh. The total variable costs per year are then calculated by multiplying energy demand by the energy rate per kWh. Thus, the total variable cost per year is IDR. 44,012,160. The investment calculation is carried out with several alternative subsidies and operational times. Five subsidy options would be applied to battery charging station cost, electrical installation cost, and land lease cost. The following are the operating time alternatives which are presented in Table 3.

Table 3. Alternative options for operating time for battery charging station facility in the traditional market

Item	Alternative Options					
	1	2	3	4	5	6
Operational time (hour)	10	12	14	16	18	20
Number of vehicles (unit/year)	28800	34560	40320	46080	51840	57600
Energy needed (kwh)	77760	93312	108864	124416	139968	155520
Energy cost (IDR)	44,012,160	52,814,592	61,617,024	70,419,456	79,221,888	88,024,320
Income (IDR)	128,304,000	153,964,800	179,625,600	205,286,400	230,947,200	256,608,000

Alternative city government subsidies, such as 25%, 50%, 75%, and 100%, are used to assess the feasibility of investing in battery charging station infrastructure in traditional markets. The following is a comparison of the results of an investment feasibility study with indicators of ROI, PP, BEP, and NPV in Table 4.

Table 4. ROI, PP, and NPV values with subsidies on a battery charging station investment in the traditional market

	Subsidy 0%	Subsidy 25%	Subsidy 50%	Subsidy 75%	Subsidy 100%
ROI	-25%	1%	51%	200%	9449%
PP (year)	26.63	19.86	13.21	6.66	0.21
BEP (unit)	9840	9686	9533	9379	9225
NPV (IDR)	-1,005,042,474	- 634,836,174	-264,629,874	105,576,426	475,782,726

Based on the investment feasibility analysis using ROI, PP, BEP, and NPV with an operational time of 10 hours and a city government subsidy of 75% giving a positive NPV value, the payback period value is less than 10 years, namely 7.28 years and a high ROI value above 100% that is 175%.

2. Investment from the establishment of a battery swapping station in the traditional market

Table 5. Battery swapping station initial investment in the traditional market

No	Item	Total	Unit	Price (IDR)	Investment (IDR)	Economic Life (year)
1	Construction cost	6	m^2	2,000,000	12,000,000	20

2	Electrical installation	1		7,500,000	7,500,000	20
3	Battery swapping station cost	2	unit	744,168,000	1,488,336,000	20
Total					1,507,836,000	

The annual fixed cost should be considered in addition to the initial investment stated in Table 5. In the traditional market, the annual fixed cost of constructing a battery swapping station is IDR 75,536,666. The typical market investment feasibility analysis assumes that battery swapping station facilities can serve 90 e-trike and e-motorcycle units per day or 32,400 units per year, with an annual energy consumption of 87,480 kWh. The total variable costs for each year are calculated by multiplying the energy demand by the IDR 566 energy rate per kWh. With a daily operation duration of 10 hours, the total variable cost per year is IDR 49,513,680. The following are the operating time alternatives which are presented in Table 6.

Table 6. Alternative options for operating time for battery swapping station facilities in traditional markets

Item	Alternative Options					
	1	2	3	4	5	6
Operational time (hour)	10	12	14	16	18	20
Number of vehicles (unit/year)	32400	43920	60480	69120	25920	72720
Energy needed (kwh)	87480	118584	163296	186624	69984	196344
Energy cost (IDR)	49,513,680	67,118,544	92,425,536	105,629,184	39,610,944	111,130,704
Income (IDR)	365,553,000	397,695,600	547,646,400	625,881,600	234,705,600	658,479,600

The investment feasibility study for battery swapping station facilities in traditional markets is carried out by considering alternative city government subsidies, namely 25%, 50%, 75%, and 100%. The following is a comparison of the results of the feasibility test with the indicators of ROI, PP, BEP, and NPV in Table 7.

Table 7. ROI, PP, and NPV values with subsidies on a battery swapping station investment in the traditional market

	Subsidy 0%	Subsidy 25%	Subsidy 50%	Subsidy 75%	Subsidy 100%
ROI	219%	198%	345%	779%	28255%
PP (year)	6.27	6.72	4.49	2.27	0.07
BEP (unit)	1271	1262	1253	1244	1235
NPV (IDR)	539,803,590	303,129,996	680,920,296	1,058,710,596	1,436,500,896

Based on a positive analysis using ROI, PP, BEP, and NPV with an operating time of 10 hours, battery placement locations in traditional markets that can provide NPV values, and a payback period of fewer than 10 years, which is 6.27 years, a high ROI of up to 219%.

3. Investment from the establishment of a battery charging station in the mall

Table 8. Battery charging station initial investment in the mall

No	Item	Total	Unit	Price (IDR)	Investment (IIDR)	Economic Life (year)
1	Construction cost	6	m^2	2,000,000	12,000,000	20
2	Electrical installation	1		7,500,000	7,500,000	20
3	Charging station fast charging type	2	unit	729,000,000	1,458,000,000	20
Total					1,477,500,000	

Table 8 shows that the yearly fixed cost of constructing a battery charging station in a mall is IDR 33,000,000 per year, with an initial expenditure of IDR 1,447,500,000 (Table 8). Because of the site lease cost, the total fixed cost of a battery charging station in a mall is higher than in the traditional market. The battery charging station infrastructure at the mall is estimated to be able to serve 80 e-trike and e-motorcycle units per day in the investment calculation.

Thus, the annual energy usage is 93,312 kWh. While, the total variable cost per year is IDR 52,814,592.The investment feasibility of installing a battery charging station facility in the mall is calculated using a variety of different subsidies and operational timeframes. The following are the operating time options which are presented in Table 9.

Table 9. The alternative of operating time for battery charging station facilities at the mall

Item	Alternative Options					
	1	2	3	4	5	6
Operational time (hour)	10	12	14	16	18	20
Number of vehicles (unit/year)	28800	34560	40320	46080	51840	57600
Energy needed (kwh)	77760	93312	108864	124416	139968	155520
Energy cost (IDR)	44,012,160	52,814,592	61,617,024	70,419,456	79,221,888	88,024,320
Income (IDR)	128,304,000	153,964,800	179,625,600	205,286,400	230,947,200	256,608,000

The feasibility of investing in battery charging station facilities in malls is carried out by considering alternative subsidies of 25%, 50%, 75%, and 100%. The following is a comparison of the results of the investment feasibility study with indicators of ROI, PP, BEP, and NPV in Table 10.

Table 10. ROI, PP, and NPV values with subsidies on a battery charging station investment in the mall

	Subsidy 0%	Subsidy 25%	Subsidy 50%	Subsidy 75%	Subsidy 100%
ROI	-8%	25%	91%	284%	12258%
PP (year)	21.68	15.95	10.47	5.21	0.16
BEP (unit)	11275	10763	10250	9738	9225
NPV (IDR)	-897,269,129	-518,123,129	-138,977,129	996,918,871	619,314,871

Based on the investment feasibility analysis using ROI, PP, BEP, and NPV with an operational time of 12 hours and a subsidy of 75% giving a positive NPV value, the payback period value is less than 10 years, namely 5.21 years and a high ROI value above 100% that is 284%.

4. Investment from the establishment of a battery swapping station in the mall

Table 11. Battery swapping station initial investment in the mall

No	Item	Total	Unit	Price (IDR)	Investment (IDR)	Economic Life (year)
1	Construction cost	6	m^2	2,000,000	12,000,000	20
2	Electrical installation	1		7,500,000	7,500,000	20
3	Battery swapping station	2	unit	744,168,000	1,488,336,000	20
Total					1,507,836,000	

In addition to the initial investment stated in Table 11, the investment feasibility study must account for fixed costs. The annual fixed cost of constructing a battery charging station in the mall comprises maintenance, overhead, labor, and land lease costs. The entire cost per year is IDR 75,536,666. The feasibility analysis for investing in a battery swapping station facility in a mall assumes that 90 units of e-trike and e-motorcycle can be serviced in a single day. As a result, the service capacity can reach 43,920 units in a year, resulting in a yearly energy demand of 118,584 kWh. The total year variable costs are then obtained by multiplying the energy demand by the IDR 566 energy rate per kWh. Thus, the total variable cost per year is IDR. 67,118,544 with an operational time of 12 hours per day. The investment feasibility analysis is calculated using multiple different subsidies and operational timeframes for the mall's battery swapping station facility. The operating time options are shown in Table 12 and are as follows.

Table 12. Alternative options for operating time for battery swapping station facilities at the mall

Item	Alternative Options					
	1	2	3	4	5	6
Operational time (hour)	10	12	14	16	18	20
Number of vehicles (unit/year)	32400	43920	60480	69120	25920	72720

Energy needed (kWh)	87480	118584	163296	186624	69984	196344
Energy cost (IDR)	49,513,680	67,118,544	92,425,536	105,629,184	39,610,944	111,130,704
Income (IDR)	293,382,000	495,527,400	547,646,400	625,881,600	234,705,600	658,479,600

A feasibility study for battery swapping station facility investment in malls was carried out by considering alternative subsidies of 25%, 50%, 75%, and 100%. The following is a comparison of the results of the investment feasibility study with the indicators of ROI, PP, BEP, and NPV in Table 13.

Table 13. ROI, PP, and NPV values with subsidies on battery swapping station investment in the mall

	Subsidy 0%	Subsidy 25%	Subsidy 50%	Subsidy 75%	Subsidy 100%
ROI	362%	345%	568%	1223%	42707%
PP (year)	4.32	4.49	2.99	1.51	0.05
BEP (unit)	1353	1324	1294	1265	1235
NPV (IDR)	1,460,759,020	1,014,549,075	1,401,279,075	1,788,009,075	2,198,739,075

Based on the investment feasibility analysis using ROI, PP, BEP, and NPV with an operational time of 12 hours, the feasibility of investing in battery swapping stations in malls has been able to provide a positive NPV value, and the payback period value is less than 10 years, which is 4.32 years with high ROI value up to 362%.

5. Determining the location of the battery charging station and battery swapping station facilities

The mathematical model is in the form of MILP which is formulated and then the optimal value is searched using LINGO. The results of data processing without subsidies from the city government and operating time of 10 hours for traditional markets and 12 hours for malls. In addition, the selected location is a potential location that meets the requirements for the construction of battery charging station and battery swapping station. The first scenario resulting locations that will be built a battery charging station as follows: X29, X30, X31, X32, X33, X35, X36, X37, X38, X39, X40, X41, and X42. While the battery swapping stations in scenario 1 are located in these locations: X1, X3, X4, X6, X13, X30, X33, X35, X36, X37, X38, X39, X40, X41, X42, X44, and X45.
Furthermore, for the second scenario, the location-allocation of battery swapping station and charging station facilities will be determined with additional subsidies from the city government. The results of data processing with a 75% subsidy for the construction of a battery charging station facility and 10 hours of operational time for traditional markets and 12 hours for mall locations. Meanwhile, the battery swapping station facility was built without using subsidies. Furthermore, the selected locations in scenario two result in the location of the battery charging station to be built as follows: X13, X29, X30, X32, X33, X35, X36, X37, X38, X39, X40, X41, and X42. Meanwhile, for the battery swapping station facility in scenario 2, the stations are built at this location: X1, X3, X4, X13, X29, X30, X33, X35, X36, X37, X38, X39, X40, X41, X42, X44, and X45.

6. Analysis of the effect of the selling price

This section will examine how changes in selling prices affect the value of the investment feasibility indicator ROI and NPV. The selling price will be changed with a change value of -50%, -25%, -10%, 0%, 10%, 25%, 50% of the current selling price of IDR 566. The following is a table of the effect of changes in selling price on the indicator value from the investment feasibility study of the establishment of battery charging station and battery swapping station facility in Table 14.

Table 14. The effect of changes in selling prices on the investment feasibility in battery recharging station

Market				Mall			
Facility	Price Change	ROI	NPV (IDR)	Facility	Price Change	ROI	NPV
Battery-Charging Station	-50%	-111.72%	-1,551,232,602	Battery-Charging Station	-50%	-111.95%	-1,552,697,282
	-25%	-68.30%	-1,278,137,538		-25%	-59.85%	-1,224,983,205
	-10%	-42.25%	-1,114,280,499		-10%	-28.59%	-1,028,354,759
	0%	-25%	-1,005,042,474		0%	-8%	-897,269,129
	10%	-7.52%	-895,804,448		10%	13.09%	-766,183,498
	25%	19%	-731,947,410		25%	44%	-569,555,05
	50%	61.95%	-458,852,346		50%	96.46%	-241,840,975
	-50%	29.70%	-675,331,517		-50%	102.95%	-205,120,870
	-25%	77.56%	-368,099,570		-25%	167.83%	211,349,102

Battery-Swapping Station	-10%	106.28%	-183,760,402	Battery-Swapping Station	-10%	206.76%	461,231,085
	0%	125%	-60,867,623		0%	233%	627,819,074
	10%	144.57%	62,025,155		10%	258.67%	794,407,063
	25%	173%	246,364,323		25%	298%	1,044,289,047
	50%	221.15%	553,596,270		50%	362.48%	1,460,759,019

Based on these calculations, it is known that changes in selling prices can provide a positive ROI for battery charging stations at market locations with a 25% increase in selling prices, and at the mall, locations require a 10% increase in selling prices to achieve positive ROI. However, the battery charging stations at the two locations have not been able to provide a positive NPV, so the subsidy option can be used to avoid a negative NPV. The battery swapping station in traditional markets and malls can provide a positive ROI even if the selling price is discounted by 50%. However, the NPV value for the battery swapping station facility in traditional markets will only be positive if the selling price increases by 10% or IDR 1,815. Meanwhile, battery swapping stations at malls can get a positive NPV value even when the selling price is discounted by 25% or equal to the selling price of IDR1,237.5.

7. Analysis of stakeholder relationships

Solo Technopark as a provider of electric vehicle battery recharging facilities will receive assistance from the Surakarta City Government, which is eager to accelerate the use of electric vehicles, especially in Surakarta. The Surakarta City Government is expected to be able to provide capital or subsidies to electric vehicle manufacturers and providers of electric vehicle battery recharging facilities. With the increasing availability of electric vehicle battery recharging facilities in Surakarta, it is hoped that it will spur the growth of electric vehicle users and even electric vehicle manufacturers, especially in the Surakarta area. The migration of fossil-fueled vehicles to electric fuel is expected to reduce greenhouse gas emissions following Indonesia's commitment to reduce greenhouse gas emissions by 41% by 2030.

This project is also able to support the transformation of ICE vehicles into electric vehicle conversion which is a project from the Ministry of Industry of the Republic of Indonesia. Convertible vehicles have a weakness in their battery recharging feature which can only be done by charging. Therefore, the manufacture of two types of electric vehicle battery recharging facilities can overcome the problem of recharging the batteries of convertible and non-converted electric vehicles.The locations of traditional markets and malls in Surakarta also benefit from the establishment of battery charging stations and battery swapping stations. One of the benefits is the increasing number of visitors who come to the location. This condition indirectly attracts customers to visit traditional markets and malls.

6. Conclusion

This study was able to find a solution for determining the location-allocation of two types of battery recharging stations to meet the demand. This study has also considered the costs that will be minimized by using a mathematical model to determine the location-allocation of battery recharging station facilities. The results of the optimization of the mathematical model determine the total number of battery recharging stations are 30 stations consisting of 13 battery charging stations (BCS) and 17 battery swapping stations (BSS). In addition, to get a positive NPV and ROI with a payback period of fewer than 10 years, battery charging station in the traditional market can be subsidized by 75% for equipment installation, as well as a land rental with an operating time of 10 hours. For battery charging station facilities at the mall, a 75% subsidy can be provided for installation and land rental with an operational time of 12 hours. Meanwhile, battery swapping station facilities in traditional markets and malls do not require subsidies to get positive NPV, and ROI with PP less than 10 years.

In addition, this research can assist investment decision-making by analyzing investment feasibility using Break-Even Point (BEP) analysis, Net Present Value (NPV), Return on Investment (ROI), and Payback period analysis (PP). So that manufacturers or investors can have decision-making assistance to establish battery recharging station facilities. This research can also be used as a consideration and reference from the government for subsidizing the establishment of battery recharging station facilities.

This study has several weaknesses that can be used as development problems in future research. The location for the establishment of battery recharging facilities is still limited to traditional markets and malls. Other sites, such as minimarkets, coffee shops, and public parks, can also be taken into account. Then, this study has not considered recharging stations for four-wheeled vehicles. In addition, this study has not considered social aspects such as the behavior of the community and consumers towards electric vehicles.

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