Decision Support System for Determining the Location of Public Electric Charging Stations (SPLU) with Machine Learning

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Abstract— Electric vehicles are becoming increasingly popular as an environmentally friendly alternative, but the main challenge is the availability of adequate charging infrastructure. This research aims to develop a decision making system for determining the best public electric vehicle charging station (SPLU) locations utilizing machine learning. The purpose of this research is to find out the process of determining the location of Public Electric Charging Stations (SPLU) using a Machine Learning-based decision making system. This research uses quantitative methods with AHP techniques to determine the criteria weights and machine learning to recommend the best SPLU locations based on spatial data, surveys, and social media. The location recommendations are displayed in the form of an interactive digital map with visualizations of the suitability level to facilitate decision making.

Keywords— *Electricity, Locations of Public Electric Vehicle Charging Stations, Social Media*

I. INTRODUCTION

In 2016, Indonesia approved the Paris Agreement, in which the country committed to reducing greenhouse gas emissions by 2030. One of the strategies to achieve this goal is by encouraging the Indonesian population to switch from using conventional fossil fuel vehicles to electric vehicles [1][2][3]. Electric vehicles are becoming increasingly popular as an environmentally friendly alternative to fossil fuel-powered vehicles[4]. By converting durable renewable energy sources, such as solar or wind energy, into electricity, we can produce environmentally friendly electric energy [5]. The first charging station in Indonesia was initially developed by PT. PLN (Persero) and was called SPLU (Public Electricity Charging Station). However, these SPLUs were mainly designed for small-scale charging, such as for street vendors, electric bicycles, and electric motorcycles . The power capacity provided ranges from 5.5 kVA to 22 kVA, and they are only equipped with sockets without direct charging plugs. These SPLUs are generally installed in public facilities. To date, PLN has installed more than 7,000 SPLU units, with 1,922 of them located in Jakarta [6].

The National Energy General Plan (RUEN) sets a target of developing 2,200 electric cars by 2025. With this assumption, it is expected that the number of electric vehicles will reach 20,000 units in that year, and the projection will increase to 35.5 million units of electric vehicles by 2050. Along with the increase in demand for electric vehicles, the need for electricity is estimated to increase to 36.9 GWh in 2025 and reach 46.3 TWh in 2050. It is estimated that electricity production will grow at an average of 6% annually, increasing from 255 TWh to 1,581 TWh. The use of electric vehicles is expected to reduce oil fuel consumption for cars from 498 million BOE to 385 million BOE by 2050, experiencing a decrease of around 22.7%. Over the next 33 years, there is expected to be a shift in the dominance of electricity use from the household sector to the industrial sector[7].

The creation of SPLU (Public Electric Vehicle Charging Station) is a step to encourage the adoption of electric-based transportation. This facility can be used by members of the academic community to charge electric bicycles, electric cars, electric motorcycles, or even for electricity needs in outdoor activities[8]. Decision-making is a common action, but it is neither simple nor easy. This is due to the complexity of decisions that require consideration of various factors and a selection process to achieve

optimal utility [9]. Several factors need to be considered when choosing an EVCS (Electric Vehicle Charging Station) location[10], such as accessibility, visibility, land availability, and travel patterns of electric vehicle users. Additionally, driver preferences and behaviors need to be taken into account to ensure optimal utilization and adoption rates[11]. Therefore, this research aims to develop a decision-making system to determine the best EVCS locations by utilizing machine learning. Machine learning is a branch of AI that allows computers to learn from data and make predictions or decisions without being explicitly programmed. Some machine learning techniques suitable for this problem include random forest, support vector machine (SVM), and neural networks [12][13][14]. By combining geospatial data, driver preference surveys, and state-of-the-art artificial intelligence modeling techniques, the proposed system is expected to accurately predict charging demand at candidate locations and select the best EVCS locations in the target city.

However, the main challenge for the mass adoption of electric vehicles is the availability of adequate charging infrastructure. Public electric charging stations (SPLU) allow electric vehicle owners to charge their vehicles in public locations, thereby reducing their concerns about limited range. Therefore, determining the optimal location for SPLUs is very important. Making decisions is a common action, but it is neither simple nor easy. This is due to the complexity of decisions that require consideration of various factors and a selection process to achieve optimal utility[9]. Several factors need to be considered when choosing the location for a public electric vehicle charging station, such as accessibility, visibility, availability of land, and the travel patterns of electric vehicle users. Additionally, driver preferences and behavior should be taken into account to ensure optimal utilization and adoption rates [11]. Therefore, this research aims to develop a decision-making system for determining the best SPLU (public electric vehicle charging station) locations by utilizing machine learning.

II. RESEARCH METHODOLOGY

The AHP (Analytic Hierarchy Process) method is used to determine the weight of each criterion based on expert and stakeholder opinions[15][16][17]. Criteria considered in the location selection include proximity to residential areas, accessibility, availability of land, and others. After identifying the criteria and location alternatives, pairwise comparisons between criteria and alternatives are conducted to determine their relative importance. To ensure the certainty of location selection, the following criteria and alternatives are considered When determining the optimal location for electric vehicle (EV) charging stations, several key criteria must be considered: the density of EVs in the area, which indicates the demand for charging services; accessibility to users, including proximity to main roads and public facilities; adequate land availability for the station and its supporting infrastructure; the presence of stable and sufficient energy resources, potentially including renewable sources; environmental factors such as potential pollution and visual impact; and the overall operational costs, including construction, maintenance, and ongoing expenses, to ensure the economic viability of the project. By carefully evaluating these factors, planners can make informed decisions about where to place EV charging stations to best serve the needs of electric vehicle users while minimizing negative impacts and maximizing efficiency.

When considering potential locations in a specific area, several key factors that need to be taken into account include the accessibility and visibility of the site, population density and surrounding traffic, proximity to other relevant facilities, adequate electrical infrastructure support, and market potential in the region. All these aspects need to be thoroughly evaluated to determine the most strategic and advantageous location. The SPLU location with the highest priority value is the best recommended location from the AHP model. The result of this optimal location recommendation is expected to assist in

decision-making for SPLU development planning[18]. The number of respondents to be given the Analytical Hierarchy Process (AHP) questionnaire should be at least 5-10 institutions or agencies related to the determination of the location of Public Electric Vehicle Charging Stations (SPLU). These institutions or agencies include the Department of Transportation, the Department of Energy and Mineral Resources, the Environmental Agency, the Regional Development Planning Agency (Bappeda), electric vehicle provider companies, SPLU operators (if any), and academics or researchers in related fields. In determining locations based on data from social media, this research uses web scraping techniques to collect Points of Interest (POI)[19] data and the number of user check-ins from platforms such as Foursquare, Instagram, and Facebook. This data is then integrated with spatial data of the area and the level of visits to other locations[20].

III. DISCUSSION AND RESULTS

A. Development of a Decision Making System for Determining SPLU Locations

]The web application developed specifically for this purpose represents this commitment, designed to assist PT PLN (Persero) UP3 Ambon and related stakeholders in making data-driven and analytical decisions. This application uses the Analytical Hierarchy Process (AHP) method, which is one of the methods in machine learning for evaluating and selecting SPLU locations, combining principles of practicality, efficiency, and participation into a single, easily accessible and usable web-based platform. This section will detail the development process of the application, the reasons for choosing certain technologies, and the expected benefits of using this application in the context of determining SPLU points in Ambon.

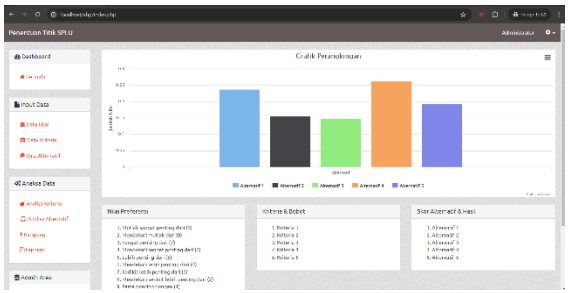

Figure 2. Display of the Decision Making System for Determining SPLU Locations

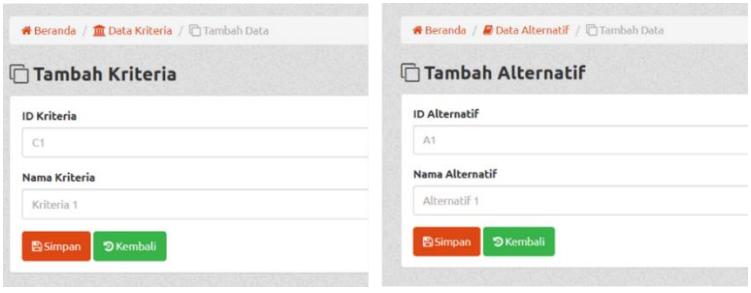

Figure 3. Interactive Dashboard for Determining SPLU Locations

B. Identify Alternative Prospective SPLU Locations in Ambon City

In order to support the transition to clean energy and reduce greenhouse gas emissions, the development of Public Electric Vehicle Charging Station (SPLU) infrastructure in Ambon City is becoming crucial. This subsection aims to identify strategic potential SPLU locations in Ambon City. This identification is based on a set of criteria including accessibility, visibility, population density, and the presence of other supporting facilities.

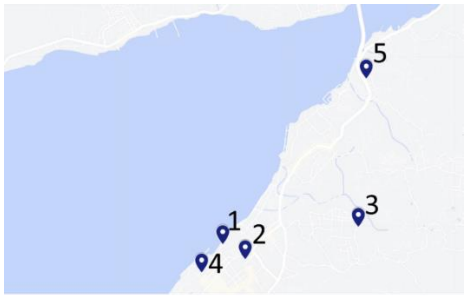

Figure 4. Alternative Locations for Ambon SPLU Locations
Source: Observation Results, 2024

Table 1. Alternative Candidate Locations for SPLU in Ambon City

Alternative	Location	GPS coordinates	Short Description
1	Mardika Beach Road	128.1802645, -3.691205	Main artery with easy access and commercial activity
2	Mardika Field – Statue of Pattimura	128.1831823, -3.6931066	Active historic location with many visitors
3	GOR Sport Hall Karang Panjang	128.1978378, -3.688899	Sports center with regular activities and events
4	Yos Sudarso Street	128.1774627, -3.6948806	The main route that is frequently traveled with high accessibility
5	Jalan Jenderal Sudirman	128.1988357, -3.6697457	Business and government areas with high traffic levels

Source: Observation Results, 2024

1. Alternative 1: Mardika Beach Road

   The first alternative is Jalan Pantai Mardika in Ambon, which is an ideal choice as a location for a Public Electric Charging Station (SPLU) due to its unique combination of accessibility, visibility, and high activity. A thorough analysis of this location provides significant insights in the context of choosing a SPLU location.

Figure 5. Alternative Condition 1
Source: Observation Results, 2024

2. Alternative 2: Mardika Field – Statue of Pattimura

   In an effort to integrate green technology with sustainable tourism development in Ambon City, Mardika Square, located near the Statue of Pattimura, offers a strategic and symbolic location for the installation of Public Electric Charging Stations (SPLU). As an important center for cultural and historical activities, this location not only attracts tourist interest but also serves as a gathering place for the local community, providing an ideal opportunity to foster eco-friendly habits through the use of electric vehicles.

Figure 6. Alternative Condition 2
Source: Observation Results, 2024

3. Alternative 3: GOR Sport Hall Karang Panjang

In the framework of developing infrastructure to support electric vehicles in Ambon City, the GOR Sport Hall Karang Panjang offers a highly potential location for the placement of a Public Electric Charging Station (SPLU). GOR Sport Hall Karang Panjang is a sports activity center and often hosts major events. Placing an SPLU at this location aims to maximize charging access for visitors arriving with electric vehicles, as well as to provide charging convenience for electronic devices while they are engaged in sports activities or watching matches.

Figure 7. Alternative Condition 3
Source: Observation Results, 2024

4. Alternative 1: Jalan Yos Sudarso

The next alternative is Yos Sudarso Street, a major artery in Ambon City that is frequently traveled by many vehicles. This location offers advantages in terms of accessibility and high visibility. The area is surrounded by various commercial facilities, making it an ideal spot for SPLU (public electric vehicle charging stations).

Figure 8. Alternative Condition 4
Source: Observation Results, 2024

5. Alternative 5: Jalan Jenderal Sudirman

Jalan Jenderal Sudirman, as one of the main arteries in the city of Ambon, offers excellent prospects as a location for a Public Electric Charging Station (SPLU). Due to its strategic and multifunctional nature, this road meets various criteria desired for the placement of electric vehicle charging infrastructure.

Figure 9. Alternative Condition 5
Source: Observation Results, 2024

C. Pairwise Comparison Analysis for Determining SPLU Locations

In the process of determining the location of Public Electric Charging Stations (SPLU) in Ambon City, the pairwise comparison matrix plays a crucial role in helping to evaluate and compare the potential of each alternative location based on predefined criteria.

Table 2. Pairwise Comparison with Each Criteria

Criteria	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5
Criterion 1	1	9,000	9,000	9,000	9,000
Criterion 2	0,111	1	9,000	9,000	9,000
Criterion 3	0,111	0,111	1	9,000	9,000
Criterion 4	0,111	0,111	0,111	1	9,000
Criterion 5	0,111	0,111	0,111	0,111	1
Amount	1,444	10,333	19,222	28,111	37,000

Source: Processed Primary Data, 2024

In interpreting this matrix, the next step is to calculate priority weights for each criterion by converting the values in the matrix into normalized weights. This is done by calculating the eigenvector of the matrix, which provides relative weights that can be used to assess each criterion overall. The results of this calculation provide clear guidance on the most advantageous candidate location for developing the SPLU based on the criteria deemed important.

Table 3. Pairwise Comparison with Each Criteria

Comparison	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	Weight
Criterion 1	0,692	0,871	0,468	0,320	0,243	0,519
Criterion 2	0,077	0,097	0,468	0,320	0,243	0,241
Criterion 3	0,077	0,011	0,052	0,320	0,243	0,141
Criterion 4	0,077	0,011	0,006	0,036	0,243	0,074
Criterion 5	0,077	0,011	0,006	0,004	0,027	0,025
Amount	1,000	1,000	1,000	1,000	1,000	1,000

Source: Processed Primary Data, 2024

The analysis of criteria weights for SPLU (electric vehicle charging station) locations reveals that Accessibility and Visibility are the most critical factors, with the highest weight of 0.519. This emphasizes the importance of easily accessible and visible sites to promote usage and electric vehicle adoption. Other significant factors include population density, traffic, and proximity to other facilities. Electrical infrastructure support is also crucial for effective operation. Market potential, while considered, has the lowest weight, suggesting it's less critical in the current context compared to other factors.

D. Weighting and Ranking Analysis in Determining SPLU Points based on Machine Learning

In AHP, weighting involves assigning weights to each criterion, reflecting its relative importance toward the final goal, which is the determination of the optimal SPLU location.

Table 4. Results of weighting criteria for alternatives

	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5
Alternative 1	0,268	0,196	0,225	0,196	0,196
Alternative 2	0,172	0,149	0,117	0,149	0,149
Alternative 3	0,152	0,146	0,144	0,146	0,146
Alternative 4	0,258	0,278	0,244	0,278	0,278
Alternative 5	0,150	0,231	0,269	0,231	0,231
Weight	0,519	0,241	0,141	0,074	0,025
Amount	1	1	1	1	1

The weighting results produced by the developed web application, as shown in Table 4, indicate the distribution of weights as follows:

- Criterion 1 (Accessibility & Visibility): Received the highest weight of 0.5189, indicating that this factor is the most influential in determining the location. This shows the importance of having SPLU (Public Electric Vehicle Charging Stations) located in areas that are easily accessible and visible to the public to increase usage and effectiveness.
- Criterion 2 (Population Density & Traffic): Given a weight of 0.2410, reflecting the importance of placing SPLU in areas with high population density and traffic to maximize reach and accessibility.
- Criterion 5 (Market Potential): Received the lowest weight of 0.0249, indicating that this factor has the least influence in location decisions compared to other criteria, but it remains relevant in the overall context of marketing strategy and SPLU development.

The next phase of the ranking process, which is a crucial step in this system, combines a comprehensive analysis of the various established criteria with the evaluation of the available location alternatives. This phase is the concluding process that integrates all aspects of the previous analysis to produce recommendations that are data-driven and objective.

Table 5. Results of Ranking of Alternative Candidate SPLU Location Points

	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	Results
Alternative 1	0,139	0,047	0,032	0,015	0,005	0,238
Alternative 2	0,089	0,036	0,017	0,011	0,004	0,156
Alternative 3	0,079	0,035	0,020	0,011	0,004	0,149
Alternative 4	0,134	0,067	0,034	0,021	0,007	0,263
Alternative 5	0,078	0,056	0,038	0,017	0,006	0,194
Amount	1,000	1,000	1,000	1,000	1,000	1,000

Source: Processed Primary Data, 2024

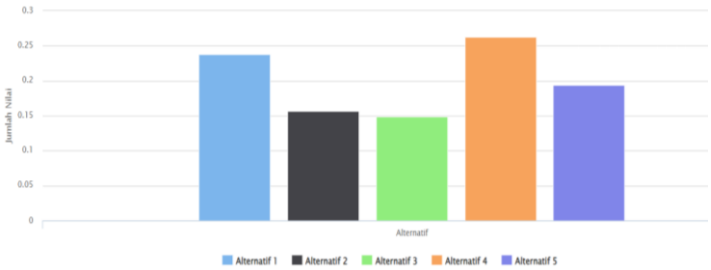

Figure 10. Graph of Alternative Assessment Results for Prospective SPLU Location Points

Source: Processed Primary Data, 2024

The ranking process uses a weighted criteria system to evaluate SPLU development locations. Alternative 4 scores highest overall, excelling in Population Density, Traffic, and Proximity to Other Facilities. Alternative 1 also performs well, particularly in Accessibility & Visibility. The methodology considers various factors crucial for SPLU success, integrating relevant data to produce comprehensive scores for each location option.

E. Machine Learning-based SPLU Point Selection and Assessment Analysis

The study evaluates potential locations for Public Electric Charging Stations (SPLU) in Ambon City using the Analytic Hierarchy Process (AHP). Five alternative sites are assessed based on five criteria: Accessibility & Visibility, Population Density & Traffic, Proximity to Other Facilities, Electrical Infrastructure Support, and Market Potential. The aim is to identify the most strategic locations to support the future adoption of electric vehicles in the city.

1. First Place: Alternative 4 (Jalan Yos Sudarso)
   Alternative 4, covering the Yos Sudarso Street area in Ambon City, has been ranked highest in the AHP assessment for Public Electric Vehicle Charging Stations (SPLU) locations. This street, a main artery of the city, excels in key criteria such as Accessibility & Visibility, Population Density & Traffic, Proximity to Other Facilities, Electrical Infrastructure Support, and Market Potential. Its central location ensures high visibility and easy access for both private and public transportation, while the surrounding area boasts various public and commercial facilities, enhancing convenience for SPLU users. The street's high population density and traffic flow guarantee optimal usage of the charging stations, while its well-integrated electrical infrastructure provides crucial support for SPLU operations. The area's strong market potential, stemming from high commercial activity and population density, indicates sustained demand for electric vehicle charging. These factors, combined with good traffic infrastructure and proximity to important amenities, make Yos Sudarso Street an excellent choice for SPLU development, aligning with long-term goals of increasing electric equipment use and supporting small and medium enterprises in Ambon City.
2. Second Place: Alternative 1 (Jalan Pantai Mardika)
   Alternative 1, Jalan Pantai Mardika in Ambon City, ranks second in the AHP analysis for Public Electric Charging Station (SPLU) locations. This strategic waterfront street excels in key criteria including Accessibility & Visibility, Population Density & Traffic, Proximity to Other Facilities, Electrical Infrastructure Support, and Market Potential. Its high accessibility and visibility ensure easy use by both locals and tourists, while its location near various recreational, culinary, and commercial facilities enhances user experience. Jalan Pantai Mardika experiences high visitor traffic, creating stable demand for charging infrastructure. The area is equipped with adequate electrical infrastructure, crucial for effective SPLU operation. Its popularity among tourists and locals, coupled with bustling commercial activities, provides

significant market potential for electric vehicle adoption and regular SPLU use. These factors combined make Jalan Pantai Mardika a highly promising location for SPLU installation, balancing practical needs with long-term goals for sustainable urban development in Ambon City.

3. Third Place: Alternative 5 (Jalan Jenderal Sudirman)
   Alternative 5, Jalan Jenderal Sudirman in Ambon City, ranks third in the AHP analysis for Public Electric Charging Station (SPLU) locations. This main road scores well in Accessibility & Visibility due to its high traffic volume and strategic position connecting various parts of the city. It also excels in Population Density & Traffic and Proximity to Other Facilities, being surrounded by important amenities like shopping centers, restaurants, and government offices. However, it lacks the unique atmosphere of higher-ranked alternatives such as beach or historical locations, which could make it less appealing to some visitors. In terms of Electrical Infrastructure Support, Jalan Jenderal Sudirman is well-served by city infrastructure but may require additional investment to manage high electrical loads from the dense commercial area. The location shows significant Market Potential due to the large number of road users and nearby businesses, promising high SPLU usage. Despite not offering the same unique aspects as higher-ranked alternatives, Jalan Jenderal Sudirman remains a competitive candidate for SPLU development with its good infrastructure and strategic central city location, ensuring effective integration with city activities.
4. Fourth Place: Alternative 2 (Mardika Field – Statue of Pattimura)
   Alternative 2, Mardika Square – Statue of Pattimura, ranks fourth in the AHP assessment for SPLU (public charging stations) locations in Ambon City. The evaluation is based on five criteria: Accessibility & Visibility, Population Density & Traffic, Proximity to Other Facilities, Electrical Infrastructure Support, and Market Potential. While Mardika Square offers good accessibility and high visibility due to its central location and historical significance, it falls short in daily population density and traffic compared to more commercial areas like Yos Sudarso Street or Jenderal Sudirman Street. The square's proximity to historical sites and its role in cultural events provide unique advantages, particularly for education and promotion of SPLUs during special occasions. However, its reliance on events for high foot traffic, potentially weaker electrical infrastructure, and lower daily usage potential compared to busier commercial areas contribute to its lower ranking. Despite these drawbacks, Mardika Square's historical value and ability to attract diverse crowds during events still make it a valuable candidate for promoting awareness of SPLU technology and sustainable energy use in Ambon.
5. Fifth Place: Alternative 3 (GOR Sport Hall Karang Panjang)
   Alternative 3, GOR Sport Hall Karang Panjang, ranks last in the AHP assessment for SPLU (Public Electric Charging Station) locations in Ambon. While it offers good accessibility as an important sports facility, it falls short in daily visibility and consistent traffic compared to busier locations like Jalan Yos Sudarso or Jalan Jenderal Sudirman. The area's lower population density and intermittent usage during events result in less optimal potential for SPLU utilization. Additionally, its proximity to facilities is limited compared to alternatives near shopping centers, restaurants, or entertainment areas that could enhance regular SPLU use. Although GOR Sport Hall Karang Panjang likely has adequate electrical infrastructure, adapting it for SPLU might require significant investment. The location's market potential for SPLU is limited to major events, contrasting with areas like Taman Pantai Air Salobar or Jalan Jenderal Sudirman that have diverse, regular visitor flows. While GOR has advantages for specific events, its lack of daily foot traffic, limited visibility, and lower accessibility make it a less optimal choice for SPLU placement compared to alternatives offering higher and more consistent public interaction.

F. Machine Learning-based SPLU Point Selection and Assessment Analysis

The use of a Machine Learning-based decision support system in determining SPLU (Public Electric Charging Stations) locations in Ambon City has yielded significant results and contributed to increasing the revenue of PT PLN (Persero) UP3 Ambon through the construction of SPLUs in strategic locations chosen based on comprehensive data analysis.

Table 6. Income from the three SPLU locations in Ambon

No.	SPLU location	GPS coordinates	Income (Rp)
1	Yos Sudarso Street	128.1774627, -3.6948806	60.860.000
2	Mardika Beach Road	128.1802645, -3.691205	49.440.000
3	Jalan Jenderal Sudirman	128.1988357, -3.6697457	12.930.000

Source: PT PLN (Persero) UP3 Ambon

PT PLN (Persero) UP3 Ambon deployed Public Electric Charging Stations (SPLU) in Ambon City using a machine learning-based decision system. The economic performance varied across three locations: Yos Sudarso Street (highest revenue: Rp 60,860,000), Mardika Beach Street (Rp 49,440,000), and General Sudirman Street (Rp 12,930,000). This implementation boosted company revenue and reduced carbon emissions, showcasing machine learning's potential in optimizing infrastructure decisions for economic and environmental gains.

IV. CONCLUSION

This research demonstrates the effectiveness of a Machine Learning-based decision support system in determining the locations of Public Electric Charging Stations (SPLU) in Ambon City. By integrating artificial intelligence technology into the infrastructure decision-making process, this study successfully identified strategic locations that not only support environmental sustainability but also enhance economic potential. The research results show that the selected locations, such as Yos Sudarso Street, generated the highest revenue, proving the accuracy of the Machine Learning model in analyzing important criteria such as accessibility, population density, and electrical infrastructure. In conclusion, the use of this advanced technology has proven capable of maximizing effectiveness and efficiency in selecting SPLU locations, providing significant direct economic impacts.

V. ACKNOWLEDGEMENT

Based on the research findings, I recommend prioritizing the construction of Public Electric Charging Stations (SPLU) in strategic locations such as Yos Sudarso Street, which has proven to generate the highest revenue. Furthermore, it is crucial to continue optimizing the use of Machine Learning-based decision support systems in determining future SPLU locations, taking into account key factors such as accessibility, population density, and electrical infrastructure. This approach will not only enhance the effectiveness and efficiency of location selection but also potentially maximize the economic impact and environmental sustainability of SPLU implementation in Ambon City.

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