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Artificial Bee Colony-Based Optimization for Public Electric Vehicle Charging Station Placement

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Abstract—Background: The urgency of developing Electric Vehicle Charging Stations (EVCS) infrastructure is increasing alongside the need for low-emission mobility and energy efficiency. **Objective:** This study aims to optimize the determination of EVCS locations using the Artificial Bee Colony (ABC) method. **Methods:** This method was selected for its capability to find optimal solutions through an iterative population-based approach. Simulations were conducted by limiting the maximum iterations to 1000 to evaluate the impact of iteration numbers on optimization quality. **Results:** The results show that the ABC method successfully identified the shortest distance from three initial locations to the optimal EVCS locations. In the second simulation, the shortest distance obtained was 0.6420 km, indicating that an increase in the number of iterations correlates directly with the quality of optimization results. Specifically, the optimal distance from the first initial location to the EVCS at Danareksa Tower was 1.7018 km using the ultra-fast charging type. From the second initial location to the EVCS at the Ministry of State-Owned Enterprises Building, the optimal distance was 0.6420 km using the fast-charging type. Meanwhile, from the third initial location to the EVCS at PLN UID Greater Jakarta, the optimal distance was 1.1787 km using the ultra-fast charging type. **Conclusion:** This study demonstrates that the ABC method can deliver accurate results in determining optimal EVCS locations with efficient distances. These findings are expected to support the development of more effective and integrated electric vehicle infrastructure.

Keywords— Electric Vehicle Charging Stations; Artificial Bee Colony; Location Optimization; Central Jakarta

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I. INTRODUCTION

Amid concerns about the climate crisis, the world is moving towards a more sustainable transportation era. One of the crucial steps is the transition from conventional vehicles that are emissive to electric vehicles[1]. The transportation industry, which accounts for 28% of global CO_2 emissions, is in the spotlight in decarbonization efforts [2-3]. *Electric vehicles* with zero emissions while driving offer an environmentally friendly and promising solution to reduce greenhouse gas emissions and dependence on fossil energy. Currently, *electric vehicles* continue to experience rapid development with the potential to become a major market in the automotive industry in the future [3-4].

The Government of Indonesia has implemented various policies and incentives to promote the adoption of *electric vehicles*, including tax exemptions, import duty reductions, and subsidies supported by Presidential Regulation Number 55 of 2019 concerning the acceleration of the battery-based electric vehicle program (KBLBB), Indonesia is intensively spurring the development of *the electric vehicle* industry along with its infrastructure, including the provision of public electric vehicle charging stations (SPKLU) [5-6]. While these measures have prompted some uptake, further incentives and infrastructure development are essential for wider EV adoption. *Electric vehicles* are here to combat air pollution by ushering in an era of environmentally friendly transportation. However, *the journey of electric vehicles* in Indonesia is still in its early stages. Limited distribution of charging station networks and marketing constraints are among the obstacles that need to be overcome immediately. This shows a significant gap between the number of *electric vehicles* and the availability of supporting infrastructure [7-8].

One of the keys to success in realizing this transition is the availability of adequate charging infrastructure [9]. This study aims to analyze in depth the *electric vehicle* charging infrastructure in Indonesia. The lack of an even and easily accessible SPKLU can cause anxiety for *electric vehicle users*, especially when traveling long distances. Concerns about running out of power in the middle of the road are the main obstacle in increasing public interest in *electric vehicles* [10-11]. Therefore, optimizing the location of SPKLU is expected to make it an alternative solution so that it is the key to supporting an effective transition to *electric vehicles* in Indonesia [13].

In this study, *the Artificial Bee Colony* (ABC) method is used because it is an algorithm as a technique in solving numerical optimization problems [14-15]. The purpose of using this method is motivated by the limited electric vehicle charging infrastructure facilities (SPKLU) in Indonesia due to the uneven distribution of SPKLU which is only concentrated on the islands of Java and Bali with limited availability in other areas so that the research is focused on especially those located in the Special Region of Jakarta, Central Jakarta City, so the author wants to

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implement it through this research so that making it a solution in determining the most optimal SPKLU location or the closest to the starting point of electric vehicle users when they need urgent charging (electric vehicle battery runs out). Central Jakarta was chosen because of the high mobility of the population in the region, driven by office centers and crowded points that require an easily accessible and integrated electric car charging infrastructure or SPKLU. Central Jakarta also has great potential for the development of SPKLU due to its high population density, rapid economic growth, and increasing energy demand. This is the right approach to optimize SPKLU infrastructure to support the adoption of electric cars and reduce carbon emissions in the city center.

Artificial bee colony optimization algorithm and its evaluative features positively affects communication in wireless networks[16]. The simple behavior of bee agents in this algorithm assist in making synchronous and decentralized routing decisions. The advantages of this algorithm is evident from the MATLAB simulations [17]. In this study, the standard ABC algorithm and its well-known variants including the gbest-guided ABC algorithm, the differential evolution based ABC/best/1 and ABC/best/2 algorithms, crossover ABC algorithm, converge-onlookers ABC algorithm and quick ABC algorithm were assessed using the electroencephalographic signal decomposition based optimization problems introduced at the 2015 Congress on Evolutionary Computing Big Data Competition[31]. In this study, the optimal power flow solution of alternating current–direct current (AC–DC) power systems is firstly accomplished by using the artificial bee colony (ABC) algorithm that is one of the heuristic methods. The proposed method is tested on two different test systems. The obtained results are compared to that of genetic algorithm (GA) and a numerical method in literature. In this study, the real transformer representation is also used for the transformers in the power systems [24]. The study on Artificial Bee Colony (ABC) in the placement of electric vehicle (EV) charging stations in public places focuses on the challenge of optimizing locations to meet the needs of EV users, which are increasing along with the trend of green mobility and energy sustainability. Electric vehicles have become a popular alternative to reduce carbon emissions and dependence on fossil fuels. However, the increasing number of EVs must be balanced with adequate charging infrastructure to meet the needs of users in urban areas and other public locations.

Optimal placement of EV charging stations is important to ensure easy accessibility for users while optimizing costs and land use efficiency. If the location of the station is not chosen carefully, congestion can occur at some stations, while other stations may be underutilized. This not only disrupts the convenience of EV users but also has the potential to increase operational costs and affect the performance of the local electricity distribution network.

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II. RESEARCH METHOD

Artificial Bee Colony (ABC) is a swarm intelligence-based optimization method inspired by the behavior of honeybees in foraging. This algorithm uses the concept of searching for food sources by worker bees, scouts, and foragers to find the optimal solution to a problem. In the context of EV charging station placement, the ABC algorithm can help determine optimal locations by minimizing total cost and maximizing service coverage. This ABC-based approach is well suited for multi-criteria optimization problems such as EV charging station placement because it is able to explore a wide solution space by considering various factors such as distance from user demand, land availability, construction costs, and grid load distribution. By using the ABC algorithm, this study is expected to provide a more efficient charging station placement solution, thereby increasing the availability of infrastructure that supports widespread EV adoption and accelerating the transition to environmentally friendly vehicles.

The optimization of the location of the Public Electric Vehicle Charging Station (SPKLU) was carried out through a simulation using *the Artificial Bee Colony* (ABC) method implemented with MATLAB software. This method aims to determine the most optimal SPKLU location or the closest to the starting point of electric car users. The stages of the research methodology applied in this study are presented in figure 1.

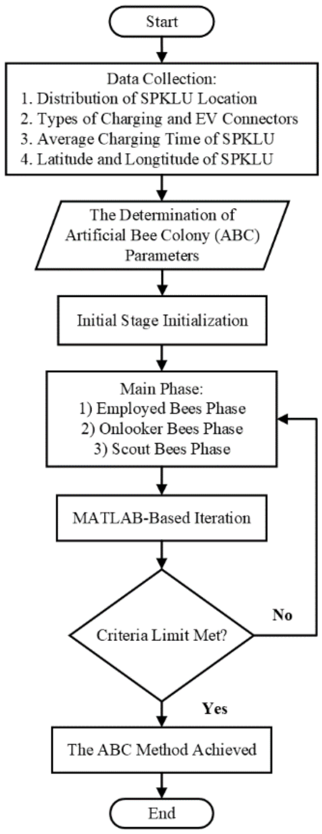

Fig 1. Flowchart

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For the application of *the Artificial Bee Colony* (ABC) method using MATLAB software, several specific parameters that have been established in this study are required. These parameters are designed to ensure the accuracy and efficiency of the simulation in determining the optimal location of SPKLU. The parameters include *Solution Number* (SN), *Maximum Cycle Number* (MCN), and *limit*. SN refers to the number of bees used in this study, while MCN indicates the maximum number of iterations to be carried out. The limit parameter is used to set the maximum iteration limit that is allowed to fix a solution before it is considered stagnant and replaced by a new solution. Details of the parameters used in this study are presented in table 1.

Table 1. Parameters of the Artificial Bee Colony

Parameters	**Value**
Solution Number (SN)	3 Bees
Maximum Cycle Number (MCN)	1000 Cycle
Limit	5
Population	10

This research is focused on the analysis of Public Electric Vehicle Charging Stations (SPKLU) located in Central Jakarta and owned by PT PLN (Persero). The data used in this study is sourced from secondary data obtained from PT PLN (Persero) Distribution Main Unit (UID) Greater Jakarta. The data was analyzed using the PLN Mobile application to obtain accurate and relevant information [10]. The method used in this study is the *Artificial Bee Colony* (ABC) scheme which aims to optimize the location of SPKLU by considering the closest distance from the initial location of electric car users. The analogy and application of the ABC scheme in determining the optimal location of SPKLU can be seen in table 2. This approach is expected to make a significant contribution to improving the efficiency and accessibility of charging stations for electric car users in the Central Jakarta area.

Table 2. The Analogy of The ABC Scheme for Public EV Charging Station Location Optimization

The Term in ABC	**Optimal Point Determination**
Food Source	Solution
Cycle	Iteration
Position of The Food Source	Position of The Solution
Best Food Source	Best Solution

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III. RESULT AND DISCUSSION

A. First Location Simulation Results

The first initial location is a trip from *Grand Indonesia West Mall* to the optimal location of SPKLU, which has been simulated using MATLAB using *the Artificial Bee Colony* (ABC) scheme. Details of the simulation results for this first location can be seen in table 3.

Table 3. First Location Simulation Results

Iteration	Code	Location	Charging Type
1	S3	EV Charging Station at Danareksa Tower	*Ultra-Fast Charging*
10	S4	EV Charging Station at BNI Tower	*Fast Charging*
50	S3	EV Charging Station at Danareksa Tower	*Ultra-Fast Charging*
100	S10	EV Charging Station at Brilian 1	*Fast Charging*
500	S3	EV Charging Station at Danareksa Tower	*Ultra-Fast Charging*
1000	S3	EV Charging Station at Danareksa Tower	*Ultra-Fast Charging*

From the results of this first location simulation, it can be observed that the use of more iterations (in this study, reaching a maximum of 1000 iterations) results in a more accurate solution. The simulation results show that the EV Charging Station at Danareksa Tower, which is equipped with *an ultra-fast charging facility*, is produced as an optimal location for the use of electric cars in accordance with the specifications and needs of the electric car. Details of the distance between *Grand Indonesia West Mall* and EV Charging Station at Danareksa Tower can be seen in figure 2.

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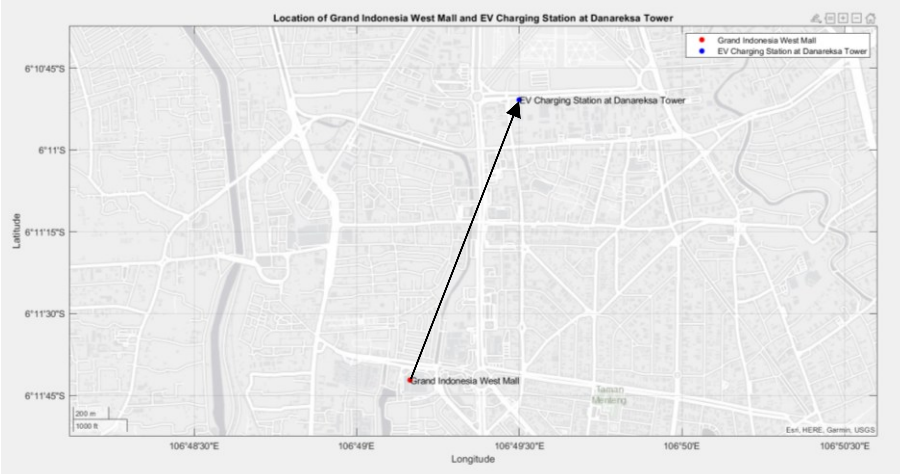

Fig 2. Location of Grand Indonesia West Mall and EV Charging Station at Danareksa Tower

In Figure 2, the simulation results show that the first location has 1.7018 kilometers (km). This distance measurement uses the ABC method and Haversine distance calculation which is a standard in location optimization research. However, these results do not consider the variables of traffic density in the region which can have a significant effect on the actual travel time.

B. Second Location Simulation Results

The second initial location is a trip from Park Hyatt Jakarta to the optimal location of SPKLU, which has been simulated using MATLAB using *the Artificial Bee Colony* (ABC) scheme. Details of the simulation results for this first location can be seen in table 4.

Table 4 .Second Location Simulation Results

Iteration	Code	Location	Charging Type
1	S3	EV Charging Station at Danareksa Tower	*Ultra-Fast Charging*
10	S2	EV Charging Station at The Ministry of State-Owned Enterprises Building	*Fast Charging*
50	S3	EV Charging Station at Danareksa Tower	*Ultra-Fast Charging*
100	S3	EV Charging Station at Danareksa Tower	*Ultra-Fast Charging*
500	S3	EV Charging Station at Danareksa Tower	*Ultra-Fast Charging*
1000	S2	EV Charging Station at The Ministry of State-Owned Enterprises Building	*Fast Charging*

From the results of this second location simulation, it can be observed that the use of more iterations (in this study, reaching a maximum of 1000 iterations) results in a more accurate

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solution. The simulation results show that the EV Charging Station at The Ministry of State-Owned Enterprises Building which is equipped with *fast charging facilities* is produced as the optimal location for the use of electric cars in accordance with the specifications and needs of the electric car. Details of the distance between Park Hyatt Jakarta and EV Charging Station at The Ministry of State-Owned Enterprises Building can be seen in figure 3.

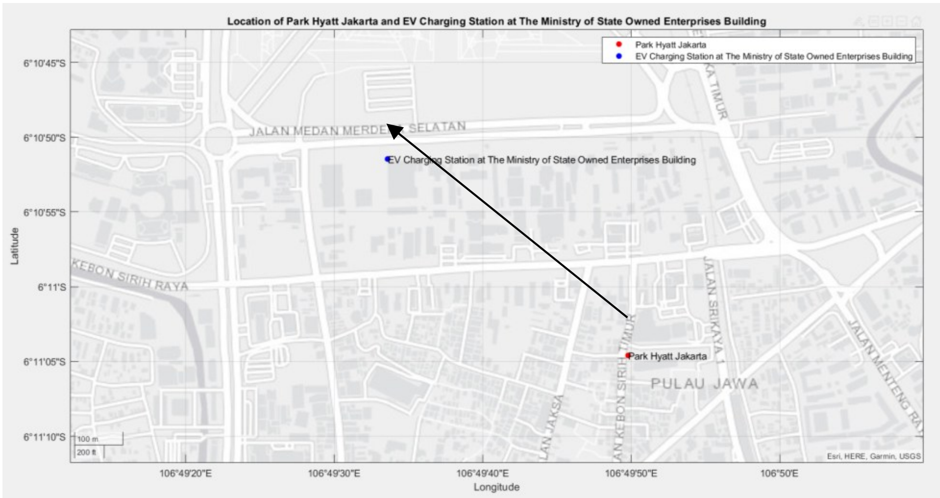

Fig 3. Location of Park Hyatt Jakarta and EV Charging Station at The Ministry of State-Owned Enterprises Building

In Figure 3, the simulation results show that the second location has 0.6420 kilometers (km). This distance measurement uses the ABC method and Haversine distance calculation which is a standard in location optimization research. However, these results do not consider the variables of traffic density in the region which can have a significant effect on the actual travel time.

C. Third Location Simulation Results

The third initial location is the journey from the Istiqlal Mosque to the optimal location of SPKLU, which has been simulated using MATLAB using the *Artificial Bee Colony* (ABC) scheme. Details of the simulation results for this first location can be seen in table 5.

Table 5. Third Location Simulation Results

Iterasi	Kode	Lokasi	Jenis Pengisian
1	S7	EV Charging Station at Pool Damri Kemayoran	*Ultra-Fast Charging*
10	S9	EV Charging Station at BNI Tower	*Fast Charging*
50	S10	EV Charging Station at Brilian 1	*Fast Charging*
100	S3	EV Charging Station at Danareksa Tower	*Ultra-Fast Charging*
500	S3	EV Charging Station at Danareksa Tower	*Ultra-Fast Charging*

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Iterasi	Kode	Lokasi	Jenis Pengisian
1000	S1	EV Charging Station at PLN UID Greater Jakarta	*Ultra-Fast Charging*

From the results of this third location simulation, it can be observed that the use of more iterations (in this study, i.e. reaching a maximum of 1000 iterations) results in a more accurate solution. The simulation results show that the EV Charging Station at PLN UID Greater Jakarta which is equipped with *ultra-fast charging facilities* is produced as the optimal location for the use of electric cars in accordance with the specifications and needs of the electric car. Details of the distance between Istiqlal Mosque and EV Charging Station at PLN UID Greater Jakarta can be seen in figure 4.

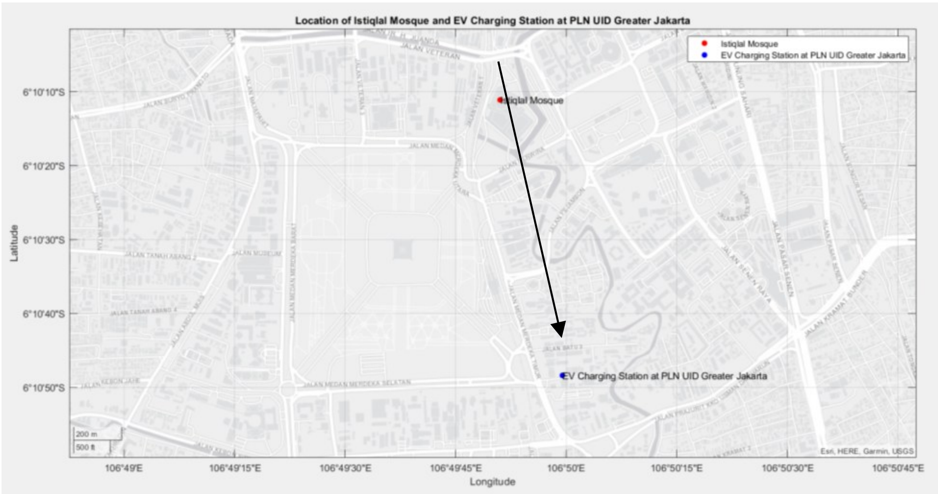

Fig 4. Location of Istiqlal Mosque and EV Charging Station at PLN UID Greater Jakarta

In Figure 4, the simulation results show that the third location has 1.1787 kilometers (km). This distance measurement uses the ABC method and Haversine distance calculation which is a standard in location optimization research. However, these results do not consider the variables of traffic density in the region which can have a significant effect on the actual travel time.

D. Comparison of Optimization Results

To see the effectiveness of the use of *the Artificial Bee Colony* (ABC) scheme in optimizing the determination of the location of SPKLU, a comparison was made of the three simulation results that had been obtained. The results of the simulation comparison of the number of iterations against the shortest distance obtained can be seen in the figure of graph 5.

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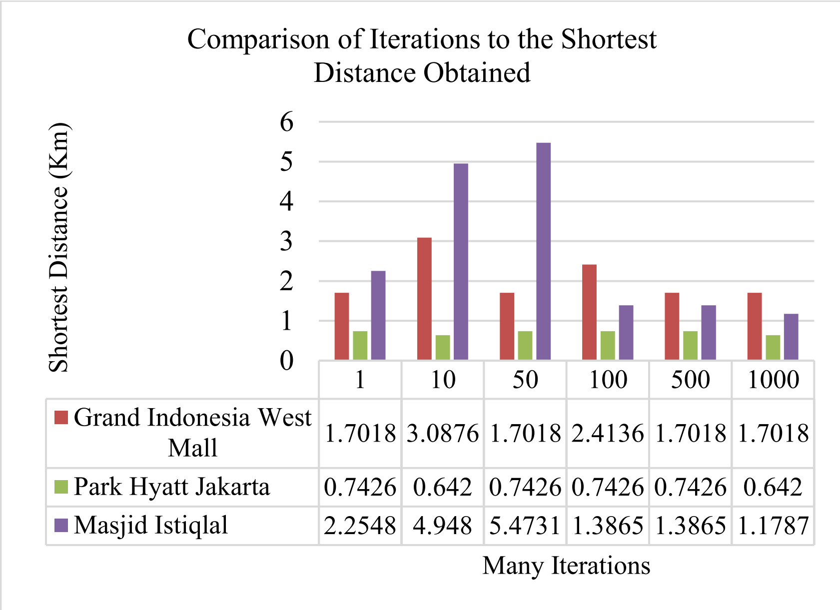

Fig 5. Comparison Chart of Iteration Variations Against the Shortest Distance

The results in graph 5 show that of the three initial locations simulated up to the 1000th iteration, the shortest distance is obtained. In conclusion, the more iterations used, the more optimal the distance will be. The use of these iterations can be continued until the maximum number is reached, but in this thesis research, the author limits it to only 1000 iterations. The results of SPKLU optimization using the ABC scheme based on MATLAB software are shown in table 6.

Table 6. EV Charging Station Optimization Results with MATLAB Based ABC Scheme

No.	User Location	Optimal Location	Charging Type	Generated Distance (km)
1.	Grand Indonesia West Mall	EV Charging Station at Danareksa Tower	*Ultra-Fast Charging*	1,7018
2.	Park Hyatt Jakarta	EV Charging Station at Ministry of State-Owned Enterprises Building	*Fast Charging*	0,6420
3.	Istiqlal Mosque	EV Charging Station at PLN UID Greater Jakarta	*Ultra-Fast Charging*	1,1787

Based on the results of SPKLU optimization in table 6 above, it was found that the optimal distance and type of charging for electric car users were found. The analysis shows that the first initial location from *Grand Indonesia West Mall* to EV Charging Station at Danareksa Tower has the closest distance that can be reached is 1.7018 km with the type of *ultra-fast charging*. Meanwhile, the second initial location from Park Hyatt Jakarta to EV Charging Station at Ministry of State-Owned Enterprises Building has an optimal closest distance of 0.6420 km with the type

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of *fast charging*. If ultra-fast charging is required, users are advised to direct their journey to the EV Charging Station at Danareksa Tower which is the optimal location in the 500th iteration. Furthermore, the third initial location from Istiqlal Tower to EV Charging Station at PLN UID Greater Jakarta has the closest distance that can be reached is 1.1787 km with the type of *ultra-fast charging*.

IV. CONCLUSION

Based on the research conducted for the Optimization of the Location Determination of Public Electric Vehicle Charging Stations (SPKLU) using *the Artificial Bee Colony* (ABC) method, it can be concluded that the *Artificial Bee Colony* (ABC) optimization method by limiting the maximum iteration to 1000 iterations shows that the shortest distance from the initial three locations to the destination location of SPKLU was successfully obtained as far as 0.6420 km in the second simulation. These results indicate that the increase in the number of iterations is directly proportional to the quality of the optimization results. The simulation showed the accuracy of the optimal distance from the first initial location to the EV Charging Station at Danareksa Tower with 1.7018 km using the *ultra-fast charging* type. Then, from the second initial location to the EV Charging Station at Ministry of State-Owned Enterprises Building with 0.6420 km using *the fast-charging* type. Furthermore, from the third initial location to the EV Charging Station at PLN UID Greater Jakarta with 1.1787 km using the *ultra-fast charging type*.

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