



DEFINING AN OPTIMAL EV CHARGING SERVICE RADIUS: A USER-BASED APPROACH FOR URBAN PLANNING IN PEKANBARU CITY

MENENTUKAN RADIUS LAYANAN PENGISIAN DAYA KENDARAAN LISTRIK YANG OPTIMAL: PENDEKATAN BERBASIS PENGGUNA UNTUK PERENCANAAN KOTA DI KOTA PEKANBARU

Ardiansyah Putra^{1*}, Wan Muhammad Yunus², Zulkarnain Umar³

¹University of Riau, Email: ardiansyahputra85@gmail.com

²University of Riau, Email: yunuswan64@gmail.com

³University of Riau, Email: zulkarnain.z@lecturer.unri.ac.id

*email koresponden: ardiansyahputra85@gmail.com

DOI: <https://doi.org/10.62567/micjo.v3i2.2446>

Abstract

The growing emphasis on sustainable urban mobility has positioned electric vehicles (EVs) as a strategic component of transport transformation, particularly in developing cities with constrained infrastructure systems. One of the key challenges in supporting EV adoption is the provision of accessible charging infrastructure, which is closely related to user perception of acceptable service distance. This study aims to determine the optimal service distance of Electric Vehicle Charging Stations (EVCS) based on user preferences in Pekanbaru City, Indonesia, and to explore its implications for spatial planning. A quantitative approach was employed using a questionnaire survey of 51 respondents distributed across 15 administrative districts. All respondents were non-EV users, representing potential adopters in the early stage of transition. The survey captured preferred EVCS distance using interval-based categories, along with respondents' awareness and intention toward EV adoption. The results indicate that the dominant preferred distance falls within the 2–4 km range, with an estimated mean of 3.08 km and a standard deviation of 1.98 km, resulting in an effective range of approximately 1–5 km. Considering urban road network constraints and detour factors, this range is further adjusted to 3–6 km to reflect more realistic travel conditions. These findings suggest that a relatively dense and accessible charging network is required to reduce range anxiety and support EV adoption. From a spatial planning perspective, a 4 km service threshold is proposed as a practical reference for EVCS deployment, representing the central tendency of user preferences within the adjusted range. This study highlights the importance of integrating user-based spatial parameters into infrastructure planning and contributes to the literature by emphasizing the role of perceived accessibility in shaping EV infrastructure demand in developing urban contexts.

Keywords : Electric Vehicles, EV Charging Stations, Service Distance, Spatial Planning, Sustainable Transport, User Preference.

Abstrak

Perhatian terhadap mobilitas perkotaan berkelanjutan telah menempatkan kendaraan listrik (EV) sebagai salah satu komponen strategis dalam transformasi sistem transportasi, khususnya di kota-kota



berkembang yang masih menghadapi keterbatasan infrastruktur, khususnya di kota-kota berkembang yang masih menghadapi keterbatasan kesiapan infrastruktur. Salah satu tantangan utama dalam mendukung adopsi EV adalah penyediaan infrastruktur pengisian daya yang mudah diakses, yang berkaitan erat dengan persepsi pengguna terhadap jarak layanan yang dapat diterima. Penelitian ini bertujuan untuk menentukan jarak layanan optimal Stasiun Pengisian Kendaraan Listrik Umum (SPKLU) berdasarkan preferensi pengguna di Kota Pekanbaru, Indonesia, serta mengkaji implikasinya terhadap perencanaan spasial. Penelitian ini menggunakan pendekatan kuantitatif melalui survei kuesioner terhadap 51 responden yang tersebar di 15 kecamatan. Seluruh responden merupakan non-pengguna kendaraan listrik yang merepresentasikan calon pengguna pada tahap awal transisi. Survei ini mengukur preferensi jarak terhadap SPKLU menggunakan kategori berbasis interval, serta tingkat pengetahuan dan minat responden terhadap penggunaan kendaraan listrik. Hasil penelitian menunjukkan bahwa preferensi jarak dominan berada pada rentang 2–4 km, dengan estimasi rata-rata sebesar 3,08 km dan standar deviasi sebesar 1,98 km, sehingga menghasilkan rentang efektif sekitar 1–5 km. Dengan mempertimbangkan keterbatasan jaringan jalan perkotaan dan faktor deviasi perjalanan (detour factor), rentang tersebut selanjutnya disesuaikan menjadi 3–6 km untuk merefleksikan kondisi perjalanan yang lebih realistis. Temuan ini menunjukkan bahwa dibutuhkan jaringan infrastruktur pengisian daya yang relatif padat dan mudah diakses untuk mengurangi kecemasan jarak tempuh (range anxiety) serta mendukung peningkatan adopsi kendaraan listrik. Dari perspektif perencanaan wilayah, penelitian ini mengusulkan ambang batas layanan sebesar 4 km sebagai acuan praktis dalam pengembangan SPKLU, yang merepresentasikan kecenderungan pusat dari preferensi pengguna dalam rentang yang telah disesuaikan. Penelitian ini menekankan pentingnya integrasi parameter spasial berbasis pengguna dalam perencanaan infrastruktur serta berkontribusi pada literatur dengan menunjukkan bahwa persepsi terhadap aksesibilitas memiliki peran penting dalam membentuk kebutuhan infrastruktur kendaraan listrik di konteks perkotaan berkembang.

Kata Kunci : Kendaraan Listrik, SPKLU, Jarak Layanan, Perencanaan Spasial, Transportasi Berkelanjutan, Preferensi Pengguna.

1. INTRODUCTION

In the context of urban planning, the availability of charging infrastructure constitutes a critical spatial component in supporting sustainable mobility. In Indonesia, this infrastructure is known as Electric Vehicle Charging Stations (EVCS/SPKLU). As of 2024, the number of electric vehicles in Pekanbaru City is estimated at approximately 1,329 units, based on local government data, while only 18 charging stations are currently available, as identified through the PLN Mobile application. This condition indicates a gap between EV growth and supporting infrastructure provision.

The transition toward electric vehicles (EVs) has become a key strategy in achieving sustainable urban transport systems and reducing greenhouse gas emissions in cities worldwide. As part of the broader concept of sustainable mobility, EV adoption is closely linked to infrastructure readiness, policy support, and user acceptance. In developing urban contexts, however, the transition process faces multiple challenges, particularly related to limited infrastructure availability and uncertainty in user behavior (International Energy Agency, 2022).

One of the most critical components in supporting EV adoption is the availability of Electric Vehicle Charging Stations (EVCS). Previous studies have highlighted that insufficient charging infrastructure remains one of the primary barriers to EV adoption, often leading to what is commonly referred to as range anxiety, or the fear of running out of battery without access to charging facilities (Rezvani et al., 2015).

In addition, existing literature suggests that accessibility to charging infrastructure, particularly in terms of spatial proximity, plays a significant role in shaping user perception and adoption intention. Users tend to prefer charging facilities located within a reasonable distance from their daily activity centers, especially residential areas (Gnann et al., 2018).



However, most previous studies have been conducted in developed countries, where infrastructure networks are relatively mature and EV adoption has reached a more advanced stage. In contrast, developing cities such as Pekanbaru are still in the early phase of EV transition, where infrastructure provision remains limited and user behavior is largely driven by perception rather than actual usage experience. This creates a research gap in understanding how potential users rather than existing EV users perceive infrastructure needs, particularly in terms of acceptable service distance.

Pekanbaru City, as the capital of Riau Province, represents a rapidly growing urban area with increasing transport demand and environmental pressure. Despite the growing awareness of EV technology, the availability of EVCS in the city remains limited and spatially uneven. This condition raises an important planning question regarding how far users are willing to access charging facilities in their daily mobility. Understanding this spatial preference is essential for defining service coverage and guiding infrastructure deployment strategies in urban areas.

This study adopts a user preference approach to estimate the optimal service distance of EVCS in Pekanbaru City. Unlike conventional studies that rely on existing EV users, this research focuses on non-EV users as potential adopters, reflecting early-stage transition conditions. The analysis is based on survey data collected from respondents across multiple administrative districts, with emphasis on perceived accessibility and distance tolerance.

This study offers the following contributions:

1. Empirical Contribution

This study provides empirical evidence on preferred EVCS service distance based on potential users in a developing urban context, addressing the lack of data in early-stage EV adoption environments.

2. Methodological Contribution

The study applies a user preference-based approach by transforming categorical distance responses into quantitative measures, enabling the estimation of mean distance, dispersion, and service thresholds for planning purposes.

3. Planning Contribution

From a regional and urban planning perspective, this study introduces a practical service distance threshold that can be used as a spatial parameter in EV infrastructure planning, supporting the development of a more accessible and demand-responsive charging network.

2. RESEARCH METHOD

This study adopts a quantitative approach to estimate the ideal spatial distance of Electric Vehicle Charging Stations (EVCS) from residential locations in an urban context. The analysis focuses on identifying an acceptable service radius that can minimize range anxiety and support early-stage electric vehicle (EV) adoption in Pekanbaru City.

The study integrates descriptive statistics and probabilistic modelling, combining respondent perception data with spatial interpretation. This approach is consistent with transport planning studies that assess user preference thresholds in the absence of fully developed infrastructure systems.

Primary data were collected through a structured questionnaire distributed to 51 respondents residing in Pekanbaru City. The respondents were selected using a purposive sampling approach, where inclusion criteria were defined to ensure relevance to the study objectives, including residence in Pekanbaru and age above 18 years. This approach was adopted due to the limited number of existing EV users in the study area, focusing instead on potential adopters in the early transition phase. Key characteristics of respondents include age range 25–45 years (productive age group). All respondents are non-EV users, representing potential adopters in the early transition phase. Respondents demonstrate high awareness and interest in EVs, based on Likert-scale responses.

The questionnaire included a key variable “Preferred distance to EVCS from residence, measured using categorical intervals with option < 2 km, 2 – 4 km, 4 – 6 km, and > 6 km”. This variable serves as the basis for estimating the ideal service coverage radius.



To enable quantitative analysis, categorical responses were transformed into numerical values using midpoint approximation, as commonly applied in transport preference studies.

Table 1. Midpoint Assignment for EVCS Distance Categories

Distance Category	Midpoint Value (km)
< 2 km	1
2 – 4 km	3
4 – 6 km	5
> 6 km	7

(conservative estimate)

The distance categories used in the questionnaire were developed based on preliminary observation of existing EVCS distribution in Pekanbaru City, as well as practical urban travel considerations. The selected intervals (<2 km, 2–4 km, 4–6 km, >6 km) are intended to capture variations in perceived accessibility within an urban context. This transformation allows the dataset to be treated as a continuous variable, enabling further statistical analysis.

To obtain an ideal distance range comparable to studies such as Pevec et al. (2020), this study applies a three-stage analytical framework:

1. Weighted Mean Estimation

The ideal distance is first estimated using a weighted mean formula:

$$\bar{x} = \frac{\sum f_i x_i}{\sum f_i}$$

Where:

- f_i = frequency of responses
- x_i = midpoint value

This provides the central tendency of preferred EVCS distance.

2. Standard Deviation and Acceptable Range

To capture variability in user preferences, the standard deviation (SD) is calculated:

$$SD = \sqrt{\frac{\sum f_i (x_i - \bar{x})^2}{pv}}$$

The effective service range is then defined as:

$$\text{Effective Range} = \bar{x} \pm SD$$

This method follows the logic used in EV infrastructure planning studies, where:

- Lower bound represents minimum acceptable proximity
- Upper bound represents maximum tolerable travel distance

This is equivalent to the concept of user tolerance threshold in transport accessibility analysis. The calculation of weighted mean and standard deviation follows standard statistical procedures in quantitative analysis (Field, 2013).

3. Scenario Adjustment for Planning Context

Since all respondents are non-EV users, their responses tend to reflect conservative (shorter) distance preferences due to perceived range anxiety. To address this bias and align with real-world planning conditions, an adjusted scenario analysis is introduced:

- Lower bound fixed at user expectation (\approx 2–3 km)
- Upper bound expanded using behavioural tolerance assumptions (up to 6–7 km)

This produces a policy-relevant planning range, rather than a purely perception-based estimate.

From a regional planning perspective, the resulting distance range is interpreted as service coverage radius for EVCS placement, basis for identifying service gaps (blank spots) and input for developing a network-based EVCS distribution model. This aligns with spatial planning principles emphasizing for accessibility, service coverage, and integration with urban mobility patterns.



This study conceptualizes EVCS distance preference as a function of perceived accessibility, psychological comfort (range anxiety) and early-stage adoption behaviour. The output is a quantitative planning parameter that can be used to guide infrastructure allocation, zoning strategies and sustainable transport planning policies.

3. RESULT AND DISCUSSION

Results

The analysis of respondent preferences reveals a clear tendency toward relatively short acceptable distances between residential locations and Electric Vehicle Charging Stations (EVCS). Based on responses from 51 participants, the distribution of preferred distances is presented as follows:

Table 2. Distribution of Respondents Based on Preferred EVCS Distance

Distance Category	Number of Respondents
< 2 km	18
2 – 4 km	19
4 – 6 km	8
> 6 km	6

The distribution indicates a strong concentration of preferences within the 2–4 km range, suggesting that spatial proximity remains a critical factor in shaping public perception of EV infrastructure accessibility, particularly in the early stage of EV adoption. To quantify the central tendency of these preferences, a midpoint approximation combined with weighted statistical calculation was applied. The results are summarized as follows:

Table 3. Statistical Summary of Preferred EVCS Distance

Indicator	Value (Km)
Mean Distance	3.08
Standard Deviation	1.90
Lower Bound	1.18
Upper Bound	4.98

These findings indicate that, statistically, the majority of respondents prefer EVCS to be located within an approximate range of 1–5 km from their residence.

It is important to note that all respondents in this study are non-EV users. Therefore, the observed preferences reflect perceived accessibility rather than actual user experience. In the context of emerging EV markets, such perceptions are often influenced by range anxiety, leading to more conservative distance expectations.

From a spatial planning perspective, a planning-oriented interpretation is adopted to account for this behavioral bias. The upper bound of the preferred range is extended to reflect more realistic urban travel tolerance. Furthermore, considering the discrepancy between Euclidean (straight-line) distance and actual travel distance in urban road networks, a detour index assumption is introduced.

Furthermore, the mean value (3.08 km) was adopted as the central reference point for planning purposes. Consequently, this study proposes an ideal EVCS service radius of 3–6 km, which better represents a balance between user perception and practical urban mobility conditions.

Table 4. Derivation of EVCS Service Distance: Statistical and Planning-Based Approach

Type	Range
Statistically Derived Range	$\mu \pm \sigma \rightarrow 1-5$ km
Planning-Adjusted Range	3–6 km (upper bound extended using a detour factor of 1.2)

A detour factor of 1.2 is applied to adjust the statistically derived distance, reflecting the typical deviation between Euclidean and actual travel distance in urban road networks. Previous studies



indicate that detour factors in urban areas generally range between 1.2 and 1.4, depending on network connectivity and spatial configuration (Rodrigue, 2020). In this study, a conservative value of 1.2 is adopted to represent relatively efficient urban road conditions.

To visualize the spatial implications of this service range, buffer zones of 3 km and 6 km were generated around existing EVCS locations. In Figure 3.2, The green circles represent the 3 km service radius (optimal accessibility), while the red circles represent the 6 km radius (maximum acceptable tolerance). The spatial analysis reveals that several areas exhibit overlapping service coverage, indicating a concentration of EVCS in certain urban zones. However, significant service gaps (blank spots) remain, particularly along major arterial corridors and peripheral districts, including Rumbai Barat, Rumbai, Rumbai Timur, Tenayan Raya, and Kulim.

These findings highlight a mismatch between user-preferred accessibility thresholds and the current spatial distribution of EVCS, suggesting the need for a more network-oriented and spatially equitable infrastructure planning approach.

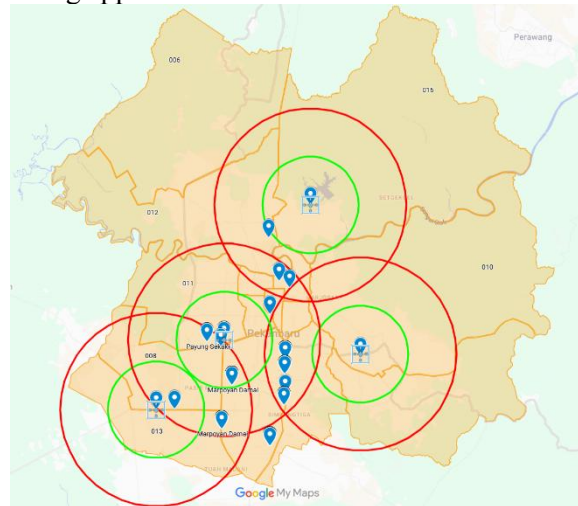


Figure Service Coverage Buffer of EVCS in Pekanbaru City

(Source: Author's analysis using Google My Maps, 2026)

Discussion

The findings indicate that distance preference is strongly influenced by perceived accessibility and psychological comfort, rather than actual usage experience. The dominance of short-distance preferences (< 4 km) reflects the presence of range anxiety, even among non-EV users. This aligns with previous studies suggesting that in early adoption phases, users tend to underestimate acceptable travel distances due to uncertainty regarding battery performance and infrastructure reliability. As a result, perceived distance thresholds are typically shorter than actual operational tolerances.

From a regional planning perspective, the estimated range of 3–6 km can be interpreted as an optimal service coverage radius for EVCS development in Pekanbaru City. This range not only reflects user expectations but also incorporates spatial and operational considerations in urban transport systems. Several key spatial implications emerge from this finding,

1. In terms of service coverage planning, the identified distance range provides a quantitative basis for determining the spatial allocation of EVCS. Areas located beyond this threshold are more likely to experience service gaps (blank spots), which may reduce accessibility and hinder EV adoption.
2. The findings highlight the need for a transition from a point-based to a network-based infrastructure system. The current distribution of EVCS in Pekanbaru remains spatially fragmented, with limited connectivity between stations. A network-based approach would enable more continuous and reliable coverage, ensuring that users remain within acceptable distance thresholds during daily mobility.
3. The integration of EVCS planning with urban mobility patterns is essential. Infrastructure deployment should not only consider residential proximity but also align with commuting flows,



commercial centers, and major urban corridors. This approach enhances functional accessibility and ensures that EVCS placement corresponds with actual travel behavior.

Furthermore, the relatively low preferred distance indicates a gap between technical feasibility and user perception. While longer travel distances may be operationally feasible, users still require a higher level of perceived accessibility to develop confidence in EV usage. This suggests that infrastructure planning should extend beyond physical provision to include aspects such as spatial visibility, distribution equity, and perceived accessibility.

Overall, these findings reinforce the argument that, in early-stage EV transition contexts, infrastructure alone is insufficient to drive adoption. Instead, infrastructure development must be integrated with strategic spatial planning, supportive policy frameworks, and user-oriented accessibility design. The identified service radius can therefore serve as a practical planning benchmark for local governments in developing EV infrastructure strategies that are both technically efficient and behaviourally responsive.

Moreover, the observed spatial mismatch indicates that EVCS deployment in Pekanbaru remains predominantly point-based rather than network-based, limiting its effectiveness in supporting city-wide EV adoption. Addressing this mismatch is critical for improving system reliability and reducing range anxiety among potential users.

This study contributes to the regional planning discourse by introducing a quantitative, user-based spatial parameter for EV infrastructure development in a developing urban context. Unlike conventional approaches that rely primarily on technical standards, this study emphasizes the integration of user perception into spatial decision-making, which is particularly relevant in cities where EV adoption is still in its early stages.

4. CONCLUSION

Based on the results and discussion, the following conclusions can be drawn:

1. User preference toward EVCS distance is strongly concentrated within short-range thresholds, with the majority of respondents indicating a preferred distance of 2–4 km. This confirms that proximity remains a critical factor influencing perceived accessibility in the early stage of EV adoption.
2. The estimated mean preferred distance of 3.08 km, with an extended planning range of 3–6 km, provides a practical spatial benchmark for EVCS service coverage. This range reflects a balance between user expectations and realistic urban travel conditions.
3. Distance perception is primarily shaped by psychological factors rather than actual experience, as all respondents are non-EV users. The presence of range anxiety leads to more conservative distance expectations, indicating that perceived accessibility plays a crucial role in shaping adoption intention.
4. The current spatial distribution of EVCS in Pekanbaru remains uneven and predominantly point-based, resulting in overlapping service areas in certain zones and significant blank spots in peripheral districts. This spatial mismatch reduces the effectiveness of infrastructure in supporting city-wide EV adoption.
5. From a regional planning perspective, EVCS development should adopt a network-based and spatially integrated approach, ensuring that infrastructure is distributed within acceptable service radii while aligning with urban mobility patterns. Incorporating user-based spatial preferences into infrastructure planning is essential for improving accessibility, reducing range anxiety, and accelerating EV adoption in emerging urban contexts. can retain loyal customers and attract new ones, while also improving overall business growth.

5. REFERENCES

Field, A. (2013). *Discovering statistics using IBM SPSS statistics (4th ed.)*. Sage Publications.



- Gnann, T., Stephens, T. S., Lin, Z., Plötz, P., Liu, C., & Brokate, J. (2018). *What drives the market for plug-in electric vehicles? A review of international PEV market diffusion models*. *Renewable and Sustainable Energy Reviews*, 93, 158–164. <https://doi.org/10.1016/j.rser.2018.03.055>
- International Energy Agency (IEA). (2019). *Global EV outlook 2019: Analysis and policy recommendations*. OECD Publishing. <https://doi.org/10.1787/35fb60bd-en>
- International Energy Agency (IEA). (2022). *An energy sector roadmap to net zero emissions in Indonesia*. <https://iea.blob.core.windows.net/assets/b496b141-8c3b-47fc-adb2-90740eb0b3b8/AnEnergySectorRoadmapToNetZeroEmissionsInIndonesia.pdf>
- International Energy Agency (IEA). (2024). *Global EV outlook 2024*. <https://www.iea.org/reports/global-ev-outlook-2024>
- Lehmann, S. (2010). *Transforming the City for Sustainability: The Principles of Green Urbanism*. Earthscan/Routledge. 10.3992/jgb.6.1.104
- Pew Research Center. (2024). *Electric vehicle charging infrastructure in the U.S.* <https://www.pewresearch.org/data-labs/2024/05/23/electric-vehicle-charging-infrastructure-in-the-u-s/>
- Pevec, D., Babic, J., Carvalho, A., Ghiassi-Farrokhfal, Y., Ketter, W., & Podobnik, V. (2020). *A survey-based assessment of how charging infrastructure affects electric vehicle transition*. *Energies*, 13(20), 5406. https://repub.eur.nl/pub/129284/Repub_129284.pdf
- PT PLN (Persero). (2026). *PLN Mobile Application* [Mobile application]. Retrieved January 2026
- Rezvani, Z., Jansson, J., & Bodin, J. (2015). *Advances in consumer electric vehicle adoption research: A review and research agenda*. *Transportation Research Part D: Transport and Environment*, 34, 122–136. <https://doi.org/10.1016/j.trd.2014.10.010>
- Rodrigue, J. P. (2020). *The geography of transport systems (5th ed.)*. Routledge.
- Zaino, R., et al. (2024). *Electric vehicle adoption: A comprehensive systematic review of determinants and barriers*. *World Electric Vehicle Journal*, 15(8), 375. <https://doi.org/10.3390/wevj15080375>
- Statistics Indonesia (BPS) Pekanbaru Municipality. (2024). *Pekanbaru Municipality in Figures 2024* [in Indonesian]. <https://pekanbarukota.bps.go.id/publication/2024/02/28/0e92e9d9c971131ee3ea3a54/kota-pekanbaru-dalam-angka-2024.html>
- Statistics Indonesia (BPS) Pekanbaru Municipality. (2024). *Population by District* [in Indonesian]. Retrieved January 28, 2026, from <https://pekanbarukota.bps.go.id/id/statistics-table/2/MjE1IzI=/jumlah-penduduk-menurut-kecamatan.html>