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Integrating AHP–GIS and Public Preference for Prioritizing Urban Rail Stations in Bandar Lampung

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Abstract

Urban rail station planning remains dominated by technical and spatial criteria, while public preferences of accessibility and convenience are rarely integrated into a single evaluation framework. This study proposes a multi-criteria decision-making framework integrated with Geographic Information Systems (GIS), in which technical scoring is evaluated using demographic–spatial indicators mapped as binary suitability layers and aggregated through the Analytic Hierarchy Process (AHP) based on expert judgement. This technical scoring is combined with Likert-scale public preference survey conducted at the same locations to compare technical scoring with user acceptance. The results reveal a strong alignment between the two assessments, while also identifying locations that are ready for development and others that require improvements to first/last-mile access and pedestrian environment quality. The proposed framework provides a transparent and practical early-stage screening tool to support decision-making in urban rail station planning, particularly in medium-sized cities with limited data availability.

Keywords: rail station siting, AHP–GIS, multi criteria decision making, public preference, infrastructure prioritization.

Abstrak

Perencanaan stasiun kereta perkotaan masih didominasi oleh kriteria teknis dan spasial, sementara persepsi pengguna terhadap aksesibilitas dan kenyamanan jarang diintegrasikan dalam satu kerangka evaluasi. Studi ini mengusulkan kerangka pengambilan keputusan multikriteria yang terintegrasi dengan *Geographic Information Systems* (GIS), di mana kesesuaian teknis dievaluasi melalui indikator demografis–spasial yang dipetakan sebagai *binary suitability layers* dan diagregasikan menggunakan *Analytic Hierarchy Process* (AHP) berbasis penilaian pakar. Penilaian ini dikombinasikan dengan survei preferensi publik berbasis skala Likert pada lokasi yang sama untuk membandingkan kelayakan the teknis dan penerimaan pengguna. Hasil menunjukkan keselarasan yang kuat antara kedua penilaian tersebut, sekaligus mengungkap lokasi yang siap dikembangkan dan lokasi yang memerlukan peningkatan akses first/last-mile dan kualitas lingkungan pejalan kaki. Kerangka ini menyediakan alat penyaringan awal yang transparan dan aplikatif untuk mendukung pengambilan keputusan dalam perencanaan stasiun kereta perkotaan di kota menengah dengan keterbatasan data.

Kata kunci: penentuan lokasi stasiun kereta. AHP-GIS, *multi criteria decision making*, preferensi publik, prioritas infrastruktur.

1. *Introduction*

Efficient and inclusive urban mobility is a key requirement for sustainable city development, particularly as rapid urbanization continues to exacerbate congestion, travel delays, and energy consumption worldwide [1]. Rail-based transit has been consistently shown to shift mode share away from private vehicles when embedded within coherent networks, thereby improving accessibility and mitigating the externalities typically associated with bus-only systems [1] [2]. Meta-analyses have further indicated that expanding urban rail infrastructure leads to increased ridership and measurable shifts from car to rail, especially in areas with high station density and strong intermodal connectivity [2]. In instances where rail service is disrupted, urban areas often experience a resurgence in road traffic and a decline in environmental quality, underscoring the structural role of rail networks [3]. From an environmental standpoint, comparative life-cycle assessments have demonstrated that rail outperforms road and air travel over equivalent passenger-kilometres, with electrification and clean traction technologies further reducing its greenhouse gas emissions [4] [5].

In Indonesia, road-based transport continues to dominate most cities outside the major metropolitan areas, resulting in significant congestion and air pollution, while the quality of public transport remains uneven across provinces [6] [7]. National-level transportation policies have encouraged the development of mass-transit infrastructure. However, numerous provincial capitals still lack dedicated, passenger-oriented rail services, making the conversion of existing rail *corridors a cost-effective and pragmatic short-term strategy [8]. Studies from comparable Asian cities suggest that the effectiveness of rail systems is strongly mediated by land-use intensity and the presence of activity nodes, which collectively influence passenger demand at the station level [2] [9].*

The city of Bandar Lampung, as the administrative and economic hub of Lampung Province, currently possesses a freight-dominated rail corridor that holds potential for passenger service conversion, provided that station locations aligns with both technical scoring and latent travel demand [9]. This potential aligns with the Masterplan for the Rejosari–Tarahan Shortcut developed by the Lampung Provincial Transportation Agency in 2013, which proposed shifting freight traffic to an alternative route, thereby enabling the existing line to serve urban transportation. Although MCDM approaches such as the Analytic Hierarchy Process supported by GIS have been widely applied to transit station siting [10], existing studies predominantly prioritize technical and spatial factors while offering limited consideration of community perceptions or social acceptability [7]. Furthermore, research incorporating public preference data remains scarce, particularly in medium-sized cities in the Global South [11] [12]. To date, no study has explicitly integrated GIS-based technical scoring with community perception data to evaluate potential station locations along active freight rail corridors in Indonesia, specifically in Bandar Lampung, leaving an important methodological and empirical gap in the literature.

Building on this gap, the present study offers a distinct methodological contribution. This study develops a lightweight, portable, and fully auditable AHP–GIS framework that integrates public-preference data through a structured Likert-scale perception survey. Unlike previous approaches that separate technical and social criteria or rely heavily on expert judgement, this framework fuses seven spatial–demographic indicators with quantified public preferences of the same candidate sites. This dual-layer integration produces a transparent comparison of technical scoring and social acceptability, providing a replicable model for data-limited urban contexts and a stronger evidence base for rail-corridor conversion in mid-sized Indonesian cities.

The primary objective of this study is to identify and prioritize suitable passenger rail station locations along the Tegineneng–Tanjung Karang corridor by integrating technical spatial analysis with user-centred perception assessments. Specifically, the study aims to: (i) conduct a transparent, criterion-based technical scoring of the proposed station sites using seven spatial–demographic indicators commonly applied in rail planning, (ii) administer a public-preference survey to evaluate the perceived suitability of the same candidate sites along the Tegineneng–Tanjung Karang corridor [12][13], and (iii) synthesize both the technical and perception-based evaluations into a unified decision-support output that generates a policy-relevant shortlist of station locations. Collectively, these objectives establish a comprehensive and context-sensitive basis for guiding evidence-based decision-making in freight-to-passenger rail conversion efforts within data-limited, medium-sized Indonesian cities.

2. *Method*

Data for this study were collected through an integrated process combining expert-based primary data and spatial–demographic secondary data to support the AHP–GIS technical scoring and public-preference assessment. Secondary spatial data included administrative boundaries, road hierarchy maps, land-use and activity-centre datasets, population grid statistics, and digitized pedestrian infrastructure, sourced from BIG, the Ministry of Transportation, OpenStreetMap (field-verified), and BPS. All layers were standardized to a common coordinate system, clipped to the study corridor, and processed in a GIS environment to generate binary suitability indicators for each criterion. Primary data were obtained through two instruments: (i) an AHP pairwise comparison survey administered to domain experts in transportation and spatial planning to derive criterion weights and consistency ratios, and (ii) a structured 5-point Likert survey targeting corridor residents and commuters to capture perceived accessibility and suitability of candidate station sites.

Technical Scoring (GIS-MCDM)

This study adopts a sequential GIS–AHP–based technical evaluation framework, consisting of GIS layer processing, AHP-based weighting, and weighted technical scoring to rank candidate station locations prior to social preference integration [13]. The choice of the Analytic Hierarchy Process (AHP) is driven by its robustness in structuring complex decision problems and its proven effectiveness in integrating qualitative and quantitative criteria [14]. Among other MCDM methods, such as ELECTRE or PROMETHEE, AHP was selected due to its ease of integration with GIS platforms and its ability to accommodate the subjective judgments of stakeholders [15]. This approach enhances the transparency and replicability of the decision-making process, making it particularly suitable for applications involving urban contexts with varied spatial-demographic factors. Seven spatial–demographic criteria commonly employed in rail station siting were operationalized: population density (A), proximity to residential areas (B), commercial and service areas (C), educational facilities (D), office areas (E), road network coverage (F), and pedestrian accessibility (G). The operational definitions, thresholds, and rationales are summarized in **Table 1** [16] [17] [18].

Table 1. Criteria and Thresholds for Technical Scoring [16] [17] [18]

Code	Operational Definition	Threshold/ Rule	Rationale
A	Persons per km² within walk-shed buffer	> 750 persons/km²	Typical urban rail access threshold in medium-density contexts
B	Residential areas intersecting walk-shed	≤ 800 m (~10-min walk)	Standard rail access radius
C	Major markets, malls, retail clusters	≤ 400 m (~5-min walk)	Daily-activity short walks
D	Schools, universities, polytechnics	≤ 400 m	Student-driven frequent trips
E	Government/ business office clusters	≤ 400 m	Peak-hour commuter demand
F	Direct access via arterial/ collector/local	Yes / No	First/last-mile integrity
G	Sidewalks/crossings present	Yes / No	Safe & convenient station access

Each criterion was mapped in a Geographic Information System (GIS) environment and encoded as a binary suitability layer (1 = meets threshold; 0 = otherwise), enabling consistent comparison across locations [19]. Distance thresholds followed standard transit-access heuristics, employing ≤400 m as an approximate 5-minute walk and ≤800 m as a 10-minute walk to key urban nodes [16] [17]. Empirical evidence supports the robustness of these thresholds, noting that passengers routinely walk within and beyond these service radii [18].

Spatial layers include administrative boundaries (1:25,000), road hierarchy, points of interest (schools, offices, markets), pedestrian facilities digitized from field verification, and 100-m population grids [19].

The spatial datasets used in this study are summarized in **Table 2**.

Following GIS-based criterion standardization, the Analytic Hierarchy Process (AHP) was applied based on expert judgment [21]. The procedure included matrix construction, eigenvector computation, and consistency ratio (CR) testing. Matrices with CR ≤ 0.10 were considered acceptable per AHP best practice. The resulting weights and ranks are shown in **Table 3**, with all CR values below the accepted threshold [22].

Table 2. Data Sources and Spatial Layers [19] [20]

Layer	Source	Year	Scale/ Resolution	Processing note
Administrative boundaries	BIG	2024	1:25,000	Clip to corridor; unify CRS
Road network (arterial/collector/local)	MoT/PU dataset	2024	1:25,000	Classify hierarchy for access
Land use & activity POIs (schools, offices, markets)	OpenStreet Map (field-validated)	2025	~10–30 m	QA/QC; deduplicate POIs
Pedestrian facilities	Field survey + hi-res imagery	2025	—	Digitize sidewalks/ crossings (binary)
Population density (grid)	BPS/statistical grid	2023	100 m	Aggregate persons/km² within walk-sheds

Table 3. AHP-based Weighting Results for Technical Scoring Parameters [22]

Parameter	Rank	AHP Weight
Population Density	1	0.266
Road Network	2	0.223
Pedestrian Network	3	0.130
Commercial & Service Areas	4	0.107
Office Areas	5	0.107
Educational Facilities	6	0.104
Residential Proximity	7	0.062

Consistency Ratio (CR) = 0,01 (<0,1)

The technical score S_i for each candidate station i was computed as a weighted sum of binary performances x_{ik} across the seven criteria, as shown in Equation (1).

$$S_i = \sum_{k=1}^{7} w_k \, x_{ik} \qquad (1)$$

where S_i denotes the technical score of candidate station i; x_{ik} represents the binary performance of station i with respect to criterion k, where $x_{ik}=1$ if station i satisfies criterion k and $x_{ik} = 0$ otherwise; w_k is the AHP-derived or equal weights normalized such that $\sum w_k=1$. For equal-weight sensitivity testing, all criteria are assigned identical weights (w_k =1/7), allowing baseline comparison and mitigating dominance from any single factor [14].

Public Preference Survey

A five-point Likert survey was used to evaluate public perceptions of the proposed station sites, enabling direct *comparison between technical feasibility and social acceptance [23]. Constructs reflected the seven technical criteria (A–G) and an overall suitability index; their mapping is shown in **Table 4** [23] [24]. Respondents were adults (≥18) living, working, or commuting within the Tegineneng–Tanjung Karang corridor.*

Table 4. *Questionnaire Blueprint [23] [24]*

Construct	Maps to	Items	Scale
Density & catchment	A	4	1–5
Residential proximity	B	3	1–5
Commerce & services	C	3	1–5
Education	D	2	1–5
Office areas	E	2	1–5
Road access	F	3	1–5
Pedestrian network	G	4	1–5

5-point Likert (1=SD ... 5=SA); higher = better perception.

Sample size was determined using the Krejcie–Morgan formula (95% confidence, 5% margin), with Cochran's method applied to check for large-population sensitivity [25] [26]. Sampling followed a stratified random approach by catchment, with time-location rotation at activity nodes (e.g., markets, schools, offices) to reduce bias [23].

Each respondent rated one or more stations based on perceived accessibility and suitability. Station-level means and 95% confidence intervals (CIs) were calculated, using listwise deletion to manage missing values and preserve validity across stations.The instrument used a 5-point Likert scale (1 = Strongly Disagree ... 5 = Strongly Agree), with higher values indicating stronger perceived access. All items were forward-written without reverse coding [27]. To ensure clarity, the tool was administered in Bahasa Indonesia and back-translated into English; pilot testing confirmed timing and semantic equivalence [28].

*Content validity was verified by 3–5 domain experts, applying thresholds of I-CVI ≥ 0.78 and S-CVI/Ave ≥ 0.90. Reliability was confirmed with Cronbach's alpha ≥ 0.70 for each construct and ≥ 0.80 for the overall scale, summarized in **Table 5** [29] [30]. All fieldwork followed standard ethics protocols, including informed consent and respondent anonymity [28].*

Table 5. *Validity and Reliability Summary [29] [30]*

Construct	I-CVI	S-CVI/Ave	α (pilot)
A–G (pooled)	≥0.78	≥0.90	≥0.78
Overall suitability	≥0.78	≥0.90	≥0.80
All items (total)			0.82

For analysis, station preferences were ranked and compared with technical scores using Spearman's rank correlation and banded cross-tabulations [24]. When applicable, Kendall's W was used to assess inter-rater agreement in expert scoring from Subsection 2.1 [21] [31].

For station prioritization, survey-based preference scores and expert-derived technical feasibility scores were jointly interpreted using an integrated correlation–quadrant framework. Following rank-based comparison, both metrics were normalized and classified into categorical bands (high, medium, and low) based on predefined threshold values to enhance interpretability. A cross-tabulation of technical feasibility and public preference bands was then used to assign stations into priority quadrants representing varying levels of implementation readiness. Stations classified in the high–high quadrant, indicating strong technical feasibility and high public acceptance, were designated as priority candidates for implementation. Stations in mixed quadrants (high–medium or medium–high) were identified as conditionally suitable, requiring targeted design adjustments or community-oriented interventions, while lower-ranking stations were deprioritized for phased or long-term consideration. This prioritization approach provides a transparent, decision-oriented mechanism linking analytical results to actionable planning outcomes.

3. *Results and Discussion*

Viewed from an administrative perspective, the railway corridor under study spans a total length of 26.864 km, traversing seven sub-districts: Natar, Rajabasa, Labuhan Ratu, Kedaton, Way Halim, Tanjung Karang Timur, and Enggal. Each of these administrative zones presents distinct demographic and spatial characteristics that shape the transportation demand of their respective communities. Variations in land use, population density, and socio-economic function underscore the need for context-sensitive planning in identifying suitable station locations along the corridor.

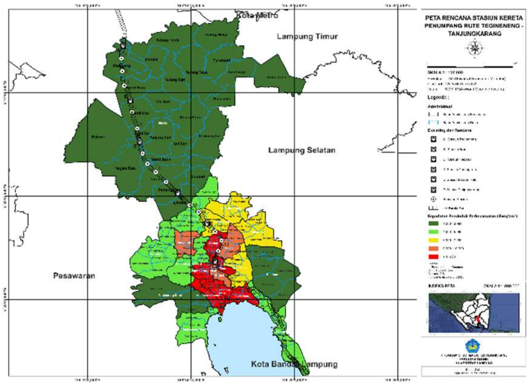

Figure 1. *Proposed Passenger Railway Station Map along the Tegineneng–Tanjung Karang Corridor*

*The maps in **Figure 1** and **Figure 2** demonstrate the linear urban structure of Bandar Lampung, with concentrated development near Raja Basa and Kedaton and more dispersed settlements toward the northern areas. Such spatial heterogeneity necessitates multi-criteria evaluation to ensure equitable accessibility.*

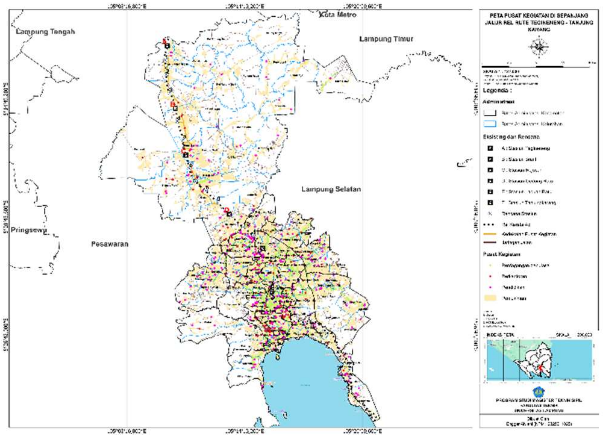

Figure 2. *Map of Activity Centers along the Tegineneng–Tanjung Karang Corridor*

Technical Scoring Results

*Candidate stations were assessed based on seven spatial–demographic criteria (A–G), using the AHP-weighted model validated with an acceptable consistency ratio (CR = 0.01), which falls well within the acceptable threshold, indicating a highly logical and consistent judgment matrix. **Table 6** summarizes binary suitability per station and the corresponding weights. Final scores and band classifications are shown in **Table 7**.*

Table 6. *Scoring Analysis*

Sta	*Variable*						
	A	*B*	*C*	*D*	*E*	*F*	*G*
Priority Weight	*0.266*	*0.062*	*0.107*	*0.104*	*0.107*	*0.223*	*0.130*
1	*1*	*1*	*0*	*0*	*0*	*1*	*0*
2	*1*	*1*	*1*	*0*	*0*	*0*	*0*
3	*1*	*1*	*1*	*0*	*1*	*1*	*1*
4	*1*	*1*	*0*	*0*	*0*	*1*	*0*
5	*1*	*1*	*0*	*0*	*0*	*0*	*0*
6	*1*	*1*	*0*	*0*	*1*	*1*	*0*
7	*1*	*1*	*1*	*1*	*1*	*1*	*1*
8	*1*	*1*	*0*	*1*	*1*	*0*	*0*
9	*1*	*1*	*0*	*0*	*0*	*1*	*0*
10	*1*	*1*	*0*	*0*	*0*	*1*	*0*
11	*1*	*1*	*1*	*1*	*1*	*1*	*1*
12	*1*	*1*	*1*	*1*	*1*	*1*	*1*
13	*1*	*1*	*1*	*1*	*0*	*1*	*1*
14	*1*	*1*	*1*	*1*	*0*	*1*	*1*

Table 7. *Scoring Results*

Sta	*Nilai Variable*							*Total*
	A	*B*	*C*	*D*	*E*	*F*	*G*	*Score*
1	*0.266*	*0.062*	*0*	*0*	*0*	*0.223*	*0*	*0.551*
2	*0.266*	*0.062*	*0.107*	*0*	*0*	*0*	*0*	*0.435*
3	*0.266*	*0.062*	*0.107*	*0*	*0.107*	*0.223*	*0.13*	*0.895*
4	*0.266*	*0.062*	*0*	*0*	*0*	*0.223*	*0*	*0.551*
5	*0.266*	*0.062*	*0*	*0*	*0*	*0*	*0*	*0.328*
6	*0.266*	*0.062*	*0*	*0*	*0.107*	*0.223*	*0*	*0.658*
7	*0.266*	*0.062*	*0.107*	*0.104*	*0.107*	*0.223*	*0.13*	*0.999*
8	*0.266*	*0.062*	*0*	*0.104*	*0.107*	*0*	*0*	*0.539*
9	*0.266*	*0.062*	*0*	*0*	*0*	*0.223*	*0*	*0.551*
10	*0.266*	*0.062*	*0*	*0*	*0*	*0.223*	*0.13*	*0.551*
11	*0.266*	*0.062*	*0.107*	*0.104*	*0.107*	*0.223*	*0.13*	*0.999*
12	*0.266*	*0.062*	*0.107*	*0.104*	*0.107*	*0.223*	*0.13*	*0.999*
13	*0.266*	*0.062*	*0.107*	*0.104*	*0*	*0.223*	*0.13*	*0.892*
14	*0.266*	*0.062*	*0.107*	*0.104*	*0*	*0.223*	*0.13*	*0.892*

Notes: High (score ≥ 0.67); Medium (0.34–0.66); Low (≤ 0.33).

Six stations achieved High feasibility (score ≥ 0.67): Sta 7, 11, and 12 scored 0.999; Sta 3 reached 0.895; Sta 13 and 14 each scored 0.892. These stations consistently fulfilled high-impact criteria, particularly A (population density), F (road network access), and G (pedestrian facilities).

Seven stations were classified as Medium: Sta 6 (0.658), 1 (0.551), 4 (0.551), 9 (0.551), 10 (0.551), 8 (0.539), and 2 (0.435). Typically, one or more critical enablers such as walkability (G=0) or proximity to activity hubs (D/E=0), were absent. Only Sta 5 (0.328) fell into the Low band, failing multiple criteria including G, F, and C, which limit feasibility.

These results highlight that criteria A, F, and G were the most decisive in shaping technical feasibility, aligning with established standards on catchment accessibility and multimodal integration. Their alignment with public preference ratings is further examined in Section 3.2. This composition accurately reflects the typical commuter profile along the corridor, capturing the perspectives of those who rely most heavily on public transit for their daily professional and academic commutes.

Public Preference Results

This subsection presents the public perception of each candidate station based on a structured survey using a 5-point Likert scale, where 1 indicates "Strongly Disagree" and 5 indicates "Strongly Agree." Higher scores reflect greater perceived accessibility and overall suitability of the proposed station location.

*Respondent demographics are summarized in **Table 8**, showing a balanced gender composition (male = 49.5%, female = 50.5%) and a majority representation from the 21–25 age group (62%). Most participants are employed in the* *private sector (46%) or are students (29%), which reflects the typical commuter profile along the corridor.*

Table 8. *Summary of the Frequency Demographics*

Category	*Number of Respondents (%)*
	Gender
Male	*49,5%*
Female	*50,5%*
	Age
17-20	*5%*
21-25	*62%*
26-30	*12%*
31-35	*8%*
36-40	*6%*
41-45	*4%*
55+	*3%*
	Job
Students	*29%*
PNS	*3%*
Private sector	*46%*
Entrepreneur	*8%*
etc	*15%*

*Based on the survey responses collected, station-level preference indices were calculated using the mean score and 95% confidence intervals (CI). These are reported and ranked in **Table 9**, which also includes the standard deviation (SD) and number of responses (n = 100 per station). Each respondent was invited to evaluate all candidate stations based on their mobility needs and travel patterns related to the locations, as well as their perceived accessibility.*

Five stations received high public preference scores (mean ≥ 4.0): Branti Raya (Sta 3), Kampung Baru (Sta 11), Kedaton (Sta 12), Merak Batin (Sta 7), and Raja Basa Raya (Sta 10). The remaining stations fall within the medium perception band (3.0–3.99). Notably, no station received a score below 3.0, indicating generally favorable perception of all proposed locations.

Table 9. *Station-level public preference*

Rank	*Station (ID)*	*Mean*	*95% CI*	*SD*
1	*Branti Raya (3)*	*4.42*	*4.22–4.62*	*1.00*
2	*Kampung Baru (11)*	*4.42*	*4.24–4.60*	*0.93*
3	*Rajabasa Raya (10)*	*4.28*	*4.08–4.48*	*1.01*
4	*Merak Batin (7)*	*4.24*	*4.03–4.45*	*1.07*
5	*Kedaton (12)*	*4.24*	*4.00–4.48*	*1.20*
6	*Surabaya-A (13)*	*3.90*	*3.66–4.14*	*1.20*
7	*Surabaya-B (14)*	*3.81*	*3.57–4.05*	*1.20*
8	*Banjar Negeri (1)*	*3.57*	*3.32–3.82*	*1.26*
9	*Candi Mas-2 (5)*	*3.55*	*3.31–3.79*	*1.20*
10	*Merak Batin-2 (6)*	*3.55*	*3.30–3.80*	*1.27*
11	*Natar (8)*	*3.51*	*3.26–3.76*	*1.26*
12	*Pemanggilan (9)*	*3.21*	*2.94–3.48*	*1.38*
13	*Haduyang (2)*	*3.39*	*3.12–3.66*	*1.36*
14	*Candi Mas-1 (4)*	*3.18*	*2.89–3.47*	*1.49*

Notes: 5-point Likert scale; High (mean ≥ 4.00); Medium (3.00–3.99); Low (< 3.00). 5-point Likert scale; higher = better perceived suitability.

The top three stations are Branti Raya (3), Kampung Baru (11), and Raja Basa Raya (10) all scored above 4.20, indicating strong social support. Meanwhile, Candi Mas-1 (4) and Pemanggilan (9) received the lowest ratings, falling below the 3.30 threshold.

The variation in mean ratings suggests that public preference is not uniform and may be driven by perceived access convenience, urban context, or safety concerns. This motivates a closer analysis of alignment between public perception and technical feasibility.

Convergence Between Technical Feasibility and Public Preference

*To evaluate the alignment between spatial feasibility and social acceptability, we compared the technical ranking in **Table 7** with public-preference scores in **Table 9**. The analysis applied Spearman's rank correlation, a non-parametric test suitable for ordinal data, to examine whether the technical feasibility of a station as captured through spatial-dynamic indicators corresponded to its perceived accessibility and attractiveness from the user's perspective.*

The result indicates a strong positive correlation ($\rho = 0.715$, $p = 0.004$, $n = 14$), signifying that stations scoring high on population density (A), collector/arterial road access (F), and continuous pedestrian paths (G) tend to be similarly rated highly by survey respondents. This statistical convergence strengthens the case for using hybrid metrics in location planning for urban transit nodes.

*To further illustrate station-level congruence between technical scores and public preferences, **Table 10** presents a cross-tabulation of stations classified into three preference bands (High ≥ 4.00, Medium 3.00–3.99, Low < 3.00) against three technical feasibility bands (High ≥ 0.67, Medium 0.34–0.66, Low ≤ 0.33).*

Tabel 10. *Cross-tabulation of technical feasibility and public preference bands*

	Preference High	*Preference Medium*	*Preference Low*	*Total*
Technical High	*4*	*2*	*0*	*6*
Technical Medium	*1*	*6*	*0*	*7*
Technical Low	*0*	*1*	*0*	*1*
Total	*5*	*9*	*0*	*14*

Notes: Technical bands: High (score ≥ 0.67); Medium (0.34–0.66); Low (≤ 0.33). Preference bands: High (mean ≥ 4.00); Medium (3.00–3.99); Low (< 3.00). 5-point Likert scale; higher = better perceived suitability

Four stations (Sta 3, 7, 11, 12) fall into the High–High quadrant, suggesting robust readiness for implementation. Two (Sta 13, 14) are High–Medium, implying potential perception gaps despite strong technical scores. One (Sta 10) shows a Medium–High pattern, indicating latent demand potentially hindered by infrastructural barriers. No station is classified as High–Low or Medium–Low, minimizing risk of rejection.

High–High stations consistently combine dense catchments (A = 1), arterial road access (F = 1), and continuous pedestrian links (G = 1). This triad likely reduces perceived travel friction. Conversely, Medium-band stations often lack G and sometimes D/E, undermining usability despite residential proximity. Results are stable under small changes in band thresholds or rank tie handling. Because ρ uses ordinal ranks, confidence interval adjustments do not affect the correlation unless mean values shift substantially.

Discussions

The four High–High stations (e.g., 3, 7, 11, 12) simultaneously exhibit high catchment density (A), direct access to arterial/collector roads (F), and continuous pedestrian infrastructure (G). This triad lowers generalized travel cost and walking effort, aligning with current transit access design, which still recognizes the 400–800 m range (~5–10 minutes) as an effective walking zone to rail nodes. Catchment areas may extend beyond this when pedestrian networks and urban form are supportive [32]. Hence, the 400/800 m benchmark applied here is not a legacy rule-of-thumb but remains empirically relevant. This convergence between technical and perceptual feasibility reinforces the validity of the sitting logic.

A strong Spearman correlation (ρ = 0.715; p = 0.004) reveals that technically sound stations are also perceived favorably by users. European station accessibility studies highlight that safety, comfort, route legibility, and pedestrian network quality captured in this model via F and G are key enablers of walking access [33]. Therefore, the overlap between technical ranking and public perception is a logical outcome rather than coincidence. In effect, variables F–G serve as mediators translating the latent benefits of A–E into real-world user experience.

Stations categorized as High–Medium (e.g., 13, 14) are infrastructure-ready but suffer perceptual gaps. Literature on first/last-mile access suggests that micro-scale interventions—such as lighting, passive surveillance, clear wayfinding, and direct pedestrian connectors—are effective in improving perceived comfort and safety without requiring heavy civil works [34]. Conversely, Medium–High sites (e.g., 10) reflect latent demand hindered by pedestrian frictions. Infill sidewalks, raised crossings, curb extensions, and direct links to activity nodes have consistently been shown to increase walking uptake and perception scores [34].

Recent evaluations warn that shared micromobility services are rarely a substitute for walking when pedestrian access is unsafe or uninviting. Without proper frontage design and pedestrian upgrades, such services underperform [35]. This reinforces the need to sequence walk-first improvements before adding technological "add-ons" particularly relevant for corridors showing perception gaps in first/last-mile access.

The use of AHP in this study remains aligned with best practices in transport siting due to its transparency in expert trade-offs and auditability. The consistency ratio of 0.01 meets standard thresholds. To further reinforce robustness, a ±5% perturbation test on weights is recommended, reporting rank stability (e.g., Spearman > 0.70) between baseline and perturbed scenarios. This approach is consistent with recent review recommendations [36].

The lightweight MCDA approach used—binary GIS layers, AHP weighting, and station-level user preference (mean + 95% CI) is congruent with emerging practices in early-phase infrastructure siting. Reporting convergence between technical feasibility and public acceptability supports multi-criteria accountability and eases replication in other mid-sized cities [37]. This integrated yet streamlined workflow suits contexts with limited data and resources.

A phased approach is proposed based on quadrant results. Phase 1 includes High–High stations (3, 7, 11, 12) for immediate concept design: platform geometry, access management, lighting, shelters, and wayfinding. Phase 1.5 targets High–Medium sites (13, 14) for placemaking upgrades at the station frontage lighting, passive surveillance, and direct pedestrian connections with micromobility added afterward [6]. Phase 2 addresses Medium–High stations (e.g., 10) via first/last-mile infill: sidewalk connections, raised crossings, curb extensions, and multimodal coordination (e.g., bus–rail schedule syncing) [3].

This study's preference scores may reflect bias toward younger commuters; land-use inputs were static. Future research could incorporate Fuzzy AHP to better handle ambiguity and uncertainty in expert judgments by combining the hierarchical structure of AHP with the strengths of fuzzy logic. Additionally, multilevel modeling may be applied to isolate cross-level effects (station–corridor–city), alongside testing alternative MCDM benchmarks (e.g., TOPSIS, VIKOR) for rank stability assessment [38]. These extensions *would further improve the framework's generalizability and rigor.*

4. Conclusion

This study develops an assessment framework that integrates AHP–GIS technical scoring with public preference evaluations to prioritize urban rail station locations along the Tegineneng–Tanjung Karang corridor. Expert pairwise comparisons produced a highly consistent weight vector (CR = 0.01), and a strong, statistically significant convergence between technical feasibility and public preference was observed (Spearman's ρ = 0.715; p = 0.004). The findings indicate that combining consistent expert-derived weights with strong public perception patterns produces a more comprehensive evaluation process, thereby strengthening the foundation for multi-criteria decision-making in early-phase transit planning. The analysis identifies four High–High candidates as suitable for Phase-1 implementation. Meanwhile, High–Medium and Medium–High sites can be enhanced through low-regret first/last-mile interventions, such as sidewalk infill, raised crossings, curb extensions, lighting, and wayfinding improvements, to reduce access frictions and enhance perceived safety and convenience.

The proposed framework is adaptable to other mid-sized, data-constrained cities, relying on transparent expert weighting, simple spatial indicators, and measurable public preference data. Accordingly, this approach provides practical and transferable guidance for policymakers and rail operators in formulating station location strategies that balance technical scoring with public preference.

This study has limitations, it does not yet include detailed cost and financial feasibility analysis, operational modelling (headways, capacity, timetable) or detailed engineering constraints at each site, and it uses relatively simple spatial indicators with equal parameter weights. Future research should couple this framework with operational and economic evaluations, explore alternative weighting schemes such as fuzzy AHP to accommodate uncertainty and partial judgments, and more detailed accessibility metrics and test the approach on other corridors and cities. Despite these limitations, the proposed method provides a practical, data-based screening tool that can guide governments and rail operators toward station choices that are both technically feasible and socially acceptable.

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