International Journal on Advanced Technology, Engineering, and Information System
https://ojs.transpublika.com/index.php/IJATEIS
Online ISSN 2828-5425

https://doi.org/10.55047/ijateis.v5i2.2327

Original Article

Development of an Instrument to Evaluate the Physical Integration of Public Transport Systems in Transit Hub

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Received : 01 June - 2026
Accepted : 24 June - 2026
Published online : 30 June - 2026

Abstract

Public transport hubs are places where public transport passengers transfer between modes. Several transit hubs in Jakarta, including the Dukuh Atas area, face physical integration issues such as the absence of minimum standards, unclear circulation, suboptimal spatial layout, and the lack of an operational evaluation instrument. This study aims to develop an instrument for evaluating the physical integration of public transport systems at transit hubs from the pedestrian perspective. The study uses the Large-scale Analytic Hierarchy Process (LAHP) to determine category and indicator weights, document analysis to formulate minimum criteria, and a user acceptance survey to assess the acceptability of physical criteria in the context of transfers between MRT Dukuh Atas and Sudirman Commuter Line Station. The results show that the Walking Distance and Transfer Time category has the highest weight of 0.4648. The three indicators with the highest global weights are Transfer Time (0.2320), Walking Distance (0.1362), and Mobility Assistance (0.0966). The user acceptance survey produced an overall mean score of 4.19 on a 1-6 scale, with 11 out of 12 indicators significantly accepted above the neutral point of 3.5. The final instrument combines LAHP global weights, minimum criteria, field measurement procedures, and a condition scoring scale, allowing it to evaluate the physical condition of transit hubs and identify priority improvements for intermodal transfer facilities.

Keywords: Evaluation, Integration, Intermodal, Public Transport, Transit Hub.

1. Introduction

A transportation system is a combination of elements and their interactions, which generates travel demand within a particular region against the provision of transportation services to meet that demand (Cascetta, 2001). According to the Ministry of Transportation, the main objectives of transportation system planning are the integration of the transportation system with land use, the availability of a sustainable urban public transport network and services, the managed ownership and use of private vehicles, the availability of pedestrian facilities integrated with public transport services, the realization of traffic engineering management in accordance with the desired level of service, the availability of fuel-efficient transportation, the realization of a competitive freight transport system, and the availability of effective access to ports and airports (Ministry of Transportation of the Republic of Indonesia, 2015).

Public transport hubs in Jabodetabek have several problems that need to be evaluated and improved, such as the absence of an intermodal integration study, unclear authority for management and oversight of transit hubs, the absence of station or stop design classifications, and the absence of a study on circulation and spatial layout. This series of problems has resulted in the absence of a design standard being used, which can lead to errors in the physical planning of transit hubs.

Engineering-related studies such as circulation, area per passenger, and specifications are often overlooked, so the output is not optimal. As a result, facilities quite often have to be renovated in order to address circulation needs or to relieve congestion. This is certainly very inefficient and also reduces user comfort. Existing approaches to evaluating transit hub integration, however, tend to address only part of this problem. Multi-criteria decision-making methods such as AHP have been used to weight and rank integration criteria based on expert judgement (Nosal & Solecka, 2014; Bryniarska & Zakowska, 2017; Yannis et al., 2020), but these instruments generally stop at expert weighting without testing whether the resulting criteria are actually acceptable to the pedestrians who use the facilities day to day. Conversely, studies that survey user perceptions of transfer experience (Chen et al., 2022; Horjus et al., 2022) rarely translate those perceptions into a weighted, prioritised set of physical design criteria that planners can act on. To date, no instrument in the Indonesian context has combined expert-based indicator weighting with a user acceptance test of the corresponding physical criteria, leaving a gap between what experts consider important and what has actually been validated as acceptable to users at the specific interchange level.

Considering the phenomenon above, a study is needed to specifically develop an instrument for evaluating the physical integration of public transport infrastructure at transit hubs, one that closes this gap by pairing indicator weighting with user acceptance testing. Through this study, it is hoped that an instrument for evaluating the physical integration of public transport systems can be produced. The general objective of this research is to develop an instrument for evaluating the integration of physical facilities of public transport systems at transit hubs from the pedestrian perspective.

2. Literature Review

2.1. Public Transport

Public transport is a mode used by the community that operates on a regular schedule and fixed route (American Public Transportation Association (APTA), 1994). Using the criteria of regularity and fixed routes, online motorcycle taxis cannot be categorized as public transport. Such a mode is categorized as charter transportation. This is also supported by Law Number 22 of 2009, which states that public transportation must guarantee the safety and comfort of its users.

2.2. Transit Hub

A transit hub is a transportation node that connects passenger transfers between services and between modes, thereby supporting the creation of an integrated transportation system (Yatskiv et al., 2017). The modern transit hub concept not only integrates various transportation modes seamlessly, but also combines physical infrastructure, mode-transfer facilities, travel information, and integrated payment systems to improve accessibility and the user experience (Horjus et al., 2022; Xanthopoulos et al., 2024). In addition to functioning as a point of mode transfer, transit hub development also aims to improve efficiency, safety, intermodality, and accessibility, as well as provide social, economic, and environmental benefits through a design that is comfortable, inclusive, and user-oriented, with service success supported by accessibility, built environment characteristics, and the availability of amenities around the transfer station (Chen et al., 2022; Taborda et al., 2023; Yatskiv et al., 2017).

2.3. Public Transport Integration

Public transport integration is an effort to unite various transportation services into a single integrated system so as to provide a seamless travel experience for users. This integration aims to increase the attractiveness of public transport, support efficient mobility, reduce congestion, and encourage the realization of sustainable transportation through better intermodal coordination (Saliara, 2014). In addition, integration also serves to provide user-friendly services through intermodal transfer facilities, integrated information systems, and the reduction of travel costs and inconvenience, thereby increasing the efficiency and effectiveness of the transportation system (Ibrahim, 2003). Furthermore, user-oriented multimodal integration enables the creation of comfortable, fast, and efficient door-to-door services, while reducing transfer costs, reducing congestion and pollution, and increasing the use of public transportation. Although intermodal transfers cannot be avoided, good transfer coordination can reduce waiting times, improve service connectivity, and create a smoother travel experience, thereby encouraging a shift from private vehicles to public transport (Li & Loo, 2016; Liu & Chen, 2019).

2.4. Multi Criteria Decision Making (MCDM)

MCDM (Multi Criteria Decision Making), or MCDA, is a decision-making method that simultaneously considers various quantitative and qualitative criteria to select the best alternative in complex problems (Nosal & Solecka, 2014; Yannis et al., 2020). In the field of transportation, this method supports the decision-making process starting from problem identification, criteria determination, alternative formulation, to the selection of the best solution in a more objective, transparent, and accountable manner, while also being able to accommodate various stakeholder interests and aspects that are difficult to assess monetarily, such as safety and environmental impact (Yannis et al., 2020). In addition to being used for the selection, classification, and ranking of decision alternatives (Nosal & Solecka, 2014), an indicator-based multi-criteria approach has also been applied to evaluate and compare the strengths and weaknesses of various interchange facilities based on aspects important to users (Bryniarska & Zakowska, 2017).

2.5. Large-scale Analytic Hierarchy Process (Large AHP)

The Large-scale Analytic Hierarchy Process (Large AHP) is a development of the Analytic Hierarchy Process (AHP) designed to solve decision-making problems with a very large number of alternatives in a big data environment (Yu et al., 2025). Unlike conventional AHP, which is effective for a limited number of alternatives due to the large number of pairwise comparisons and the increasing risk of inconsistency (Saaty, 1980), Large AHP overcomes these limitations through the grouping of alternatives using the K-means++ algorithm and evaluation based on fuzzy-rough-advantage relations. This approach enables the weighting and ranking process for hundreds to thousands of alternatives to be carried out more efficiently, consistently, and accurately compared to conventional AHP (Yu et al., 2025).

3. Methods

3.1. Research Methodology Stages

The research was conducted in stages, starting from problem identification and formulation, literature study, determination of potential indicators, indicator weighting using the Large-scale Analytical Hierarchy Process (LAHP) method, formulation of physical facility criteria, user acceptance survey, up to the compilation and validation of the physical integration evaluation instrument for public transport systems.

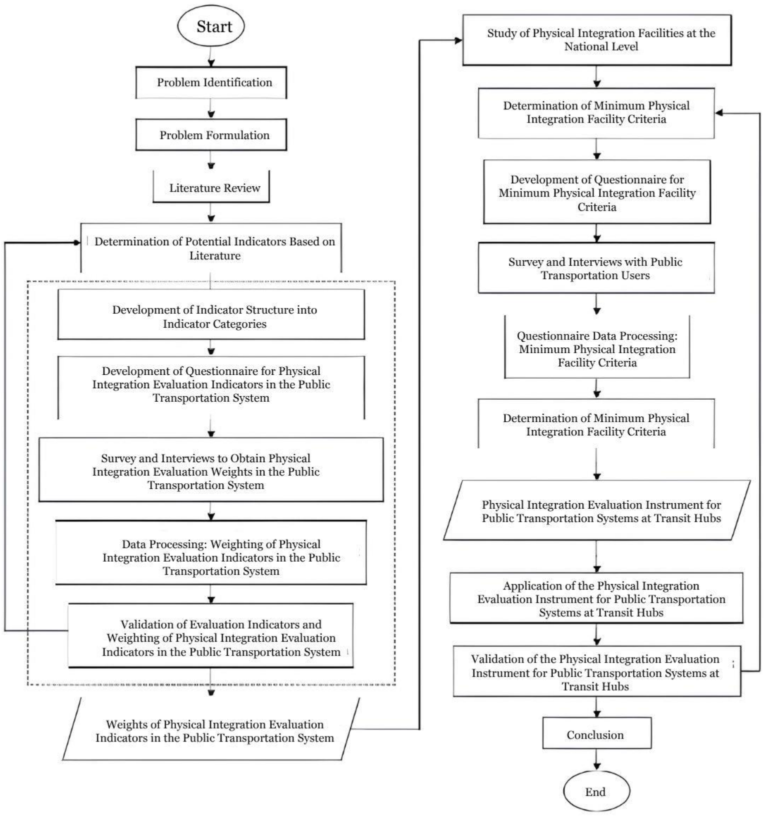

Figure 1. Research Design Flow Diagram
Source: Author's Analysis (2026)

3.2. Literature Study and Data Collection Design

A literature study was conducted to obtain a theoretical foundation and to formulate research indicators based on relevant journals and standards. Data collection involved two groups of respondents, namely experts to determine indicator weights through LAHP and public transport users to assess the level of acceptance of physical facility criteria for mode transfers.

3.3. Determination of the Potential Indicator Set

Research indicators were determined through a literature review and grouped into four categories: walking distance and mode transfer time, walking and waiting environment, pedestrian circulation, and information provision. The indicators were then prioritized using the LAHP method.

3.4. Large-scale Analytical Hierarchy Process (LAHP) Stages

The LAHP method was used to structure the indicators, develop the questionnaire, conduct the survey of experts, and process the data to produce priority weights for each indicator. The weighting results form the basis for compiling the physical integration evaluation instrument.

3.5. Determination of Criteria

The minimum physical facility criteria were formulated based on document study and tested through a survey of public transport users. The research used expert respondents for indicator weighting and user respondents to assess acceptance of the criteria, so that the resulting instrument has both a scientific basis and alignment with user needs.

3.6. Questionnaire Development

The user acceptance survey instrument contained a respondent profile and 12 assessment statements representing the research indicators. Each statement addressed a physical condition or criterion being tested, such as a walking distance of 150 meters, a transfer time of 12 minutes, the availability of escalators/elevators, roof protection, cleanliness, accessibility, lighting, pedestrian circulation, and information. A 1-6 rating scale was used, with positive-negative processing.

3.7. Sampling Method

This study used two groups of respondents. LAHP respondents were selected purposively, namely respondents who have experience, knowledge, or involvement in the fields of transportation, urban planning, civil engineering, architecture, government, or the use of public transportation. Recruitment began with a purposively identified pool of practitioners and academics meeting these criteria, supplemented by snowball referrals from initial respondents to reach individuals with relevant transit hub or intermodal planning experience. A minimum of 20 respondents was targeted for the LAHP stage, consistent with expert-panel sizes reported in prior AHP-based transport evaluation studies (Nosal & Solecka, 2014; Bryniarska & Zakowska, 2017), where expert panels of comparable size have been shown sufficient to produce consistent pairwise comparison matrices (CR < 0.10); this was corroborated in the present study by the consistency test results reported in Table 3. These respondents were used to obtain indicator weighting assessments. Meanwhile, user acceptance survey respondents were selected from public transport users relevant to the context of mode transfer, particularly users who understand or have experienced transfers in the Dukuh Atas area. The user survey was used to gauge the level of acceptance of the physical facility criteria being tested, not to statistically represent the entire population of public transport users in Jabodetabek.

3.8. Mathematical Procedure for LAHP Processing

The LAHP input consists of pairwise comparison answers from valid respondents. The hierarchical structure consists of the research objective at the first level, 4 categories at the second level, and 12 indicators at the third level. Each element within the same level is compared to its parent element.

For each pair of indicators or categories i and j, the value from respondent r is denoted as x_{ij}^{r}. Aggregation of respondent answers is done using the geometric mean: $GM_{ij} = (\prod_{r=1}^{R} x_{ij}^{r})^{1/R}$, with R being the number of valid respondents. The GM_{ij} values form the aggregate matrix $A = [a_{ij}]$. The aggregate matrix is reciprocal, so that $a_{ji} = 1/a_{ij}$ dan $a_{ii} = 1$.

The matrix columns are then normalized. The priority weight of each element is obtained from the row average of the normalized matrix. A consistency test is carried out through the calculation of the weighted sum vector, the maximum eigenvalue (λmax), the Consistency Index (CI), and the Consistency Ratio (CR). The matrix is declared consistent if CR < 0.10.

The local weight of an indicator is the weight of the indicator within its category, while the category weight is the weight of each category relative to the main objective. The global weight of an indicator is calculated by multiplying the category weight and the indicator's local weight. The final ranking of indicators is determined based on the order of global weight from largest to smallest.

4. Results and Discussion

4.1. Research Results

4.1.1. Respondent Demographics

The results of data collection using the LAHP method involved 20 unique respondents with a total of 380 main assessments and 40 tutorial assessments. Respondent characteristics were dominated by daily public transport users (80%) and respondents with 1-5 years of experience (65%). The professional backgrounds of respondents were quite varied, including transportation/urban planning, civil engineering, government, architecture, consulting, private employees, entrepreneurs, and other professions. In addition, respondent involvement in transit hub development was evenly split, with 50% having been involved and 50% not having been involved. This composition provides a picture that indicator weighting was carried out by respondents with diverse experience and backgrounds, although it was not intended to statistically represent the population of experts.

The user acceptance survey involved 134 valid respondents after the data cleaning process. Respondents were dominated by the 18-25 age group (64.2%) and the 26-35 age group (26.9%), with a relatively balanced proportion of men and women. Most respondents worked as private employees (44%) and students (32.8%), and used public transportation every day (38.1%) or several times a week (35.8%). The largest travel purpose was for commuting or work activities (55.2%), while the most commonly used transportation modes were the Commuter Line/KRL (64.9%), MRT (50%), online motorcycle taxis (39.6%), and TransJakarta buses (35.8%). These characteristics indicate that the majority of respondents are active users of the public transport system who have experience in transferring between modes, making them relevant for providing user acceptance assessments in this study, although the results still represent the research context rather than the entire population of transportation users in Jabodetabek.

4.1.2. LAHP Data Analysis

A. Category Weight Results

Table 1. LAHP Category Weights and Rankings

Rank	Code	Category	Weight	Interpretation
1	A	Walking Distance and Mode Transfer Time	0.4648	Most dominant category
2	B	Walking and Waiting Environment	0.2141	Supporting category
3	C	Walking Circulation	0.1779	Supporting category
4	D	Information Provision	0.1431	Supporting category

As shown in table 1, the category weight results show that the Walking Distance and Mode Transfer Time category is the most dominant category with a weight of 0.4648. This finding indicates that the aspect of transfer efficiency, particularly distance and transfer time, is viewed as the main foundation in evaluating the physical integration of transit hubs.

The next category is Walking and Waiting Environment with a weight of 0.2141, followed by Walking Circulation with a weight of 0.1779, and Information Provision with a weight of 0.1431. This order indicates that the quality of the environment, circulation, and information remain important, but are placed as supporting dimensions after transfer efficiency.

B. Local Indicator Weight Results

Table 2. Local Weights of Indicators Within Each Category

Category Code - Category	Indicator Code - Indicator	Local Weight	Rank Within Category
A - Walking Distance and Mode Transfer Time	A2 - Mode Transfer Time	0.4992	1
A - Walking Distance and Mode Transfer Time	A1 - Walking Distance	0.2930	2
A - Walking Distance and Mode Transfer Time	A3 - Mobility Assistance	0.2078	3
B - Walking and Waiting Environment	B2 - Facility Cleanliness	0.2926	1
B - Walking and Waiting Environment	B1 - Roof Cover	0.2692	2
B - Walking and Waiting Environment	B4 - Street Lighting	0.2200	3
B - Walking and Waiting Environment	B3 - Disability Friendliness	0.2181	4
C - Walking Circulation	C1 - Dedicated Pedestrian Path	0.4336	1
C - Walking Circulation	C3 - Crossing Reduction	0.3123	2
C - Walking Circulation	C2 - Dedicated Entry and Exit Access	0.2542	3
D - Information Provision	D2 - Directional Signage	0.5828	1
D - Information Provision	D1 - Real-Time Information Board	0.4172	2

In the transfer efficiency category, Mode Transfer Time has the highest local weight as shown in table 2. In the Walking and Waiting Environment category, Facility Cleanliness has the highest local weight, followed by Roof Cover. In the Walking Circulation category, Dedicated Pedestrian Path is the most dominant indicator. In the Information Provision category, Directional Signage is more dominant than the Real-Time Information Board.

C. Global Weight Results and Indicator Ranking

The category with the highest weight is Walking Distance and Mode Transfer Time (0.4648). Its weight differs substantially from the other three categories. This means the evaluation instrument needs to place walking distance and transfer time as important elements.

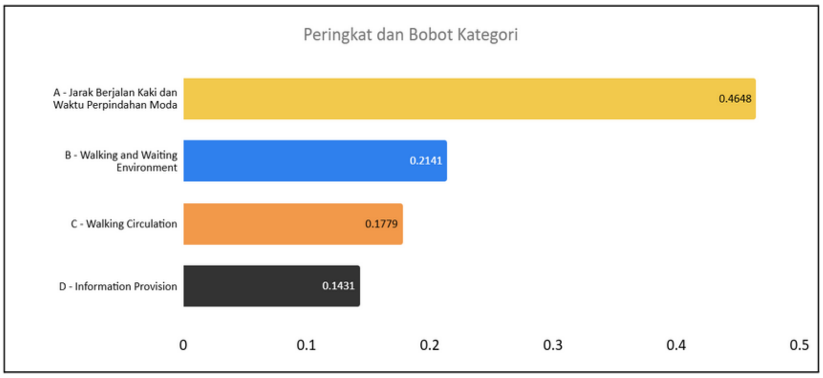

Figure 2. LAHP Category Weight Ranking

The other three categories, in order, are Walking and Waiting Environment (0.2141), Walking Circulation (0.1779), and Information Provision (0.1431). These three categories indicate that instrument items on the walking and waiting environment are more important than pedestrian circulation and information.

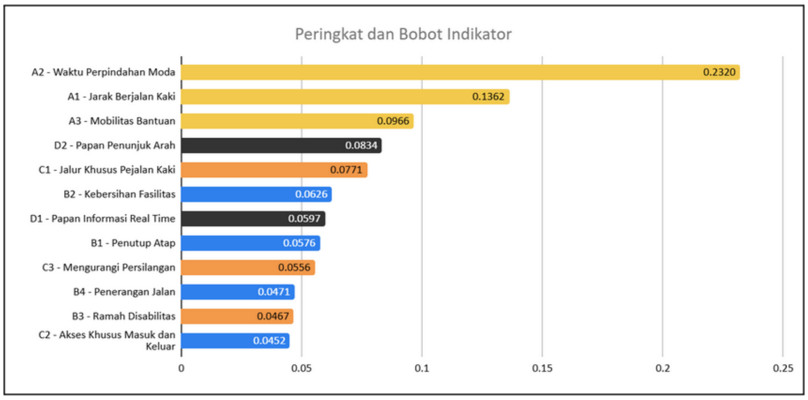

Figure 3. LAHP Indicator Ranking and Weights

The three indicators with the highest global weights are Mode Transfer Time (0.2320), Walking Distance (0.1362), and Mobility Assistance (0.0966). All three fall within the transfer efficiency category. This means that the evaluation instrument needs to place transfer efficiency as a core element.

The fourth-ranked indicator is Directional Signage (0.0834), which indicates that clarity of directional information remains an important aspect after transfer efficiency. The Dedicated Pedestrian Path indicator (0.0771) also falls within the top five because clear pedestrian paths affect the safety and smoothness of transfers.

The three indicators with the lowest global weights are Dedicated Entry and Exit Access, Disability Friendliness, and Street Lighting. A lower position in the LAHP ranking does not mean these indicators are unimportant, but rather indicates that their relative priority is lower compared to the transfer efficiency indicators and several of the information/circulation indicators.

D. Consistency Test / Validation of LAHP Results

Table 3. LAHP Matrix Consistency Test

Matrix	n	lambda_max	CI	RI	CR	Status
Category	4	4.0269	0.0090	0.9000	0.0100	Consistent
A - Walking Distance and Mode Transfer Time	3	3.0074	0.0037	0.5800	0.0064	Consistent
B - Walking & Waiting Environment	4	4.1277	0.0426	0.9000	0.0473	Consistent
C - Walking Circulation	3	3.0000	0.0000	0.5800	0.0000	Consistent
D - Information Provision	2	2.0000	0.0000	0.0000	0.0000	Consistent

As shown in table 3, all CR values are below the 0.10 threshold, so the category matrix and indicator matrices can be read as consistent. This result supports the reliability of using the weights as a basis for indicator ranking.

E. **Substantive** Interpretation **of LAHP Results**

K-Means++ and Elbow Method analysis was carried out to maintain methodological alignment with the LAHP reference paper, which uses clustering as part of the object grouping process. In this study, K-Means++ was not used to replace the conceptual categories, but to examine whether the pattern of indicator weights shows a clustering tendency that supports the four-category structure.

The K-Means++ results show that grouping indicators based on weight patterns has not fully formed balanced clusters. Therefore, the clustering results were not used as the main basis for indicator categorization. This finding reinforces the methodological decision that the research categories remain built on theory and literature synthesis, while K-Means++ is used as an exploratory check.

The Elbow Method shows the largest bend point at K=4, so the use of four clusters can be considered (Table 4). The WCSS value at K=4 is 80.1634 with a silhouette score of 0.4121. This result is consistent with the methodological needs of the research, which from the outset built four conceptual categories based on the literature.

Table 4. K-Means++ and Elbow Method Results

Analysis	Input/Method	Main Result	Interpretation
Elbow Method	K=1 to K=8	K=4 selected; WCSS 80.1634; silhouette 0.4121	K=4 is feasible to consider as a supporting number of groups.
Empirical K-Means++ K=4	Global indicator weight features per respondent; z-score	Cluster sizes: 1, 1, 2, and 8 indicators; ARI against theoretical category 0.2805	Clusters are not yet balanced and not fully aligned with the conceptual categories.
Theory-anchored K-Means	Global weight features + one-hot theoretical category with gamma=5	Aligned with the 4 theoretical categories; ARI 1.0000	Used as a supporting check, not as evidence of pure clustering.
Methodological decision	Literature synthesis + LAHP results + user survey	Final categories remain theory-based	K-Means supports the exploration process, but is not the main basis for categorization.

4.1.3. User Acceptance Survey Data Analysis

The survey results contained 154 responses and 134 valid respondents after cleansing. Overall, the mean of all items was 4.19 on a 1-6 scale, with 74.3% positive responses and 44.5% Top-2 Box. The user acceptance survey in this study was not positioned as the primary method for building a user behavior model, but rather as an acceptance test for the physical criteria that had been compiled. Therefore, the analysis used focused on descriptive statistics, testing acceptance against the neutral point, item validity, and instrument reliability. Regression, SEM, and factor analysis were not used, as these methods explain causal or latent relationships between perception variables rather than test the acceptability of predefined criteria, which was the study's aim; such methods may be appropriate in future research extending this work to modelling user behaviour or satisfaction.

Methods such as regression, SEM, or factor analysis were not used because the purpose of the study was not to explain causal relationships between perception variables, but to assess whether the criteria compiled could be accepted by users. More complex analysis can be carried out in further research if the research focus is expanded to modeling user behavior or satisfaction.

A. Descriptive Statistics Results per Indicator

Table 5. Descriptive Statistics of the User Acceptance Survey per Indicator

Indicator Code - Indicator	N	Mean	Median	Std Dev	% Positive	% Negative	Top-2 Box	Classification
A1 - Walking Distance	134	4.96	5	0.89	93.3%	6.7%	73.9%	Very well accepted
C1 - Dedicated Pedestrian Path	134	4.62	5	0.98	90.3%	9.7%	56.7%	Strongly accepted
B4 - Street Lighting	134	4.54	5	0.94	89.6%	10.4%	52.2%	Strongly accepted
D2 - Directional Signage	134	4.48	5	1.09	82.8%	17.2%	53.0%	Strongly accepted
B2 - Facility Cleanliness	134	4.38	5	1.12	76.9%	23.1%	54.5%	Strongly accepted
B3 - Disability Friendliness	134	4.19	4	1.09	79.1%	20.9%	40.3%	Accepted
B1 - Roof Cover	134	4.10	4	1.23	68.7%	31.3%	40.3%	Accepted
C2 - Dedicated Entry and Exit Access	134	4.03	4	1.19	70.1%	29.9%	38.8%	Accepted
A2 - Mode Transfer Time	134	4.01	4	1.18	71.6%	28.4%	38.1%	Accepted
A3 - Mobility Assistance	134	3.81	4	1.34	59.0%	41.0%	33.6%	Accepted with reservations
C3 - Crossing Reduction	134	3.70	4	1.12	59.7%	40.3%	26.1%	Accepted with reservations
D1 - Real-Time Information Board	134	3.51	4	1.40	50.7%	49.3%	26.9%	Accepted with reservations

As shown in table 5, the highest mean value was found for the Walking Distance indicator, with a mean of 4.96 and a positive percentage of 93.3%. This indicator can be read as the criterion most accepted by respondents. Conversely, the lowest mean was found for the Real-Time Information Board, with a mean of 3.51 and a negative percentage of 49.3%. This result indicates that the real-time information aspect remains the weakest point in user perception.

B. Sample Adequacy

The number of valid respondents, 134 people for 12 question items, indicates good sample adequacy, with an N/item ratio of 11.17, exceeding the common practice threshold of ≥10. A 95% margin of error of 8.5% is also acceptable for an exploratory survey since it is below 10%. Thus, the sample size is adequate to support descriptive analysis, reliability, and item validity, although it has not reached the 5% MOE precision standard commonly used for large-population surveys.

C. Reliability and Validity of the Survey Instrument

The overall reliability of the instrument is good, with a Cronbach's Alpha of 0.829 for 12 items and 134 valid respondents. All 12 items were declared valid because the corrected item-total correlation was greater than the r-table value of 0.170 and the p-value was below 0.05. Thus, all indicators can be retained for the user acceptance analysis.

D. Interpretation of User Acceptance per Indicator

The indicator with the highest acceptance is Walking Distance, with a mean of 4.96, a median of 5, a positive percentage of 93.3%, and a Top-2 Box of 73.9%. The next two indicators are Dedicated Pedestrian Path and Street Lighting. All three indicate that physical distance, pedestrian paths, and lighting have been relatively well accepted by users. The three indicators with the lowest acceptance are Real-Time Information Board (mean 3.51), Crossing Reduction (mean 3.70), and Mobility Assistance (mean 3.81). This result indicates that improvement efforts need to be directed not only at distance and time, but also at the certainty of information, reduction of circulation conflicts, and the quality of mobility assistance facilities.

4.1.4. Integration of LAHP Results and User Acceptance Survey

A. Indicator Priority Matrix

Table 6. Integration of LAHP Ranking and User Acceptance

Indicator	LAHP Rank	Global Weight	Mean	% Positive	Acceptance Rank	Classification	Implication
A2 - Mode Transfer Time	1	0.2320	4.01	71.6%	9	Accepted	Priority maintained
A1 - Walking Distance	2	0.1362	4.96	93.3%	1	Very well accepted	Priority maintained
A3 - Mobility Assistance	3	0.0966	3.81	59.0%	10	Accepted with reservations	Main priority for improvement
D1 - Directional Signage	4	0.0834	4.48	82.8%	4	Strongly accepted	Priority maintained
C1 - Dedicated Pedestrian Path	5	0.0771	4.62	90.3%	2	Strongly accepted	Priority maintained
B2 - Facility Cleanliness	6	0.0626	4.38	76.9%	5	Strongly accepted	Maintained
D1 - Real-Time Information Board	7	0.0597	3.51	50.7%	12	Accepted with reservations	Supporting improvement
B1 - Roof Cover	8	0.0576	4.10	68.7%	7	Accepted	Supporting improvement
C3 - Crossing Reduction	9	0.0556	3.70	59.7%	11	Accepted with reservations	Supporting improvement

Indicator	LAHP Rank	Global Weight	Mean	% Positive	Acceptance Rank	Classification	Implication
B4 - Street Lighting	10	0.0471	4.54	89.6%	3	Strongly accepted	Maintained
B3 - Disability Friendliness	11	0.0467	4.19	79.1%	6	Accepted	Maintained
C2 - Dedicated Entry and Exit Access	12	0.0452	4.03	70.1%	8	Accepted	Maintained

The priority matrix as in table 6 shows that Mobility Assistance is the main priority for improvement because it has a high LAHP weight but relatively weak user acceptance. Real-Time Information Board and Crossing Reduction also need attention even though their LAHP weights are not among the top three, as user acceptance is low or not yet statistically strong.

4.1.5. Implications for the Physical Integration Evaluation Instrument

The integration results also show that the instrument should not only assess the presence of facilities, but should also assess the quality, connectivity, and reliability of facilities. For example, the presence of an escalator/elevator is not sufficient if its capacity, location, queuing, and reliability are not yet adequate for users.

The final transit hub score is calculated using the formula: Final transit hub score = Σ (Global Weight_i × Condition Score_i), for i = 1 to 12. Because the sum of the global weights of all indicators equals 1, the final score falls within the range of 1 to 6 if the field condition score uses a 1-6 scale.

A condition score of 1 means the facility very much does not meet the criteria, 2 means it does not meet the criteria, 3 means it somewhat does not meet the criteria, 4 means it somewhat meets the criteria, 5 means it meets the criteria, and 6 means it very much meets the criteria. The following classification of final results is compiled as an operational design based on the minimum-maximum distribution of the instrument's scores, not as a standard regulatory threshold (Table 7 and Table 8).

Table 7. Design of the Physical Integration Evaluation Instrument for Transit Hubs

Indicator	Global Weight	Criteria/Condition Assessed	Measurement Method	Condition Score
Mode Transfer Time	0.2320	Actual transfer time between modes, including obstacles and waiting points.	Observation/measurement of transfer time.	1-6
Walking Distance	0.1362	Effective walking distance from the exit point of the initial mode to the connecting mode.	Measurement of the transfer path distance.	1-6
Mobility Assistance	0.0966	Availability, location, capacity, and reliability of escalators, elevators, ramps, or mobility assistance.	Facility audit and observation of usage.	1-6

Indicator	Global Weight	Criteria/Condition Assessed	Measurement Method	Condition Score
Directional Signage	0.0834	Clarity of direction toward the connecting mode, exits, platforms, stops, and important facilities.	Wayfinding audit at decision points.	1-6
Dedicated Pedestrian Path	0.0771	Availability of a pedestrian path that is safe, clear, and separated from vehicle conflicts or other flows.	Path observation and condition documentation.	1-6
Facility Cleanliness	0.0626	Cleanliness condition of the transfer path, waiting area, and supporting facilities.	Visual audit and/or checklist.	1-6
Real-Time Information Board	0.0597	Real-time information on arrivals, disruptions, connecting modes, and service changes.	Content and information placement audit.	1-6
Roof Cover	0.0576	Continuity of weather protection along the walking path and waiting area.	Coverage measurement and observation.	1-6
Crossing Reduction	0.0556	Level of conflict/crossing of pedestrian flows on the transfer path.	Observation of conflict points and flow patterns.	1-6
Street Lighting	0.0471	Adequacy of lighting on the transfer path and at decision points.	Visual audit/light measurement device where available.	1-6
Disability Friendliness	0.0467	Availability of ramps, guiding blocks, elevators, and accessible information.	Facility accessibility audit.	1-6
Dedicated Entry and Exit Access	0.0452	Clarity and separation of entry and exit access to reduce conflict and confusion.	Observation of access and layout.	1-6

Table 8. Classification of the Final Transit Hub Evaluation Score

Final Score Range	Classification	General Interpretation
1.00-1.99	Very low	Physical integration very much does not meet the minimum criteria.
2.00-2.99	Low	Many important criteria are not yet met.
3.00-3.99	Moderate	Some criteria are met, but improvement is still needed.
4.00-4.99	Good	Most criteria are met and support intermodal transfer.
5.00-6.00	Very good	Field conditions very much meet the physical integration criteria.

4.2. Discussion

The research results show that the mode transfer efficiency aspect is the most decisive component in evaluating the pedestrian physical integration of transit hubs. This is evident from the weighting results using the LAHP method, which placed Mode Transfer Time, Walking Distance, and Mobility Assistance as the three highest-priority indicators. This finding shows that users and experts view the smoothness of the transfer process as the main goal of physical intermodal integration. The shorter the time required to transfer between modes and the easier the available access, the higher the perceived quality of integration. On the other hand, the user acceptance survey results show that the walking distance indicator received a high level of acceptance, while mobility assistance did not show the same level of acceptance. This condition indicates that users can still accept a walking distance of around 150 meters as long as the transfer path is easy to traverse, comfortable, and does not create obstacles. Conversely, the availability of supporting facilities for the group of users who need mobility assistance still requires attention so that the transfer experience can be felt equally by all users.

These findings show that the quality of physical integration at a transit hub is not only determined by the proximity of locations between modes, but also by the quality of the walking experience during the transfer process. A transit hub functions as a transition space that must be able to reduce various forms of transfer cost experienced by users. This transfer cost is not only in the form of additional travel time and walking distance, but also includes confusion in finding direction, uncertainty of information, physical obstacles, conflicts in pedestrian flow movement, and discomfort due to environmental conditions. Thus, evaluation of physical integration cannot only focus on spatial measures, but needs to consider various aspects that affect the ease, comfort, safety, and accessibility during the mode transfer process. This multidimensional approach allows the physical integration condition of a transit hub to be assessed more comprehensively compared to using only distance or travel time indicators.

The research results also show consistency with various studies on intermodal integration that place transfer efficiency, pedestrian accessibility, circulation quality, information systems, and the walking environment as the main factors in creating effective mode transfers. However, this study provides an additional contribution because it does not stop at the stage of identifying indicators. Through the combination of the LAHP method and the user acceptance survey, each indicator obtains an importance weight that reflects its relative priority in the evaluation process, while also obtaining an acceptance threshold based on user perception. This approach produces an evaluation instrument that not only has a conceptual basis, but is also supported by expert consideration and user experience, making it more applicable for use in assessing the physical condition of transit hubs.

The instrument produced in this study is designed as an evaluation tool that can be used systematically to assess the level of pedestrian physical integration at various transit hubs. This instrument consists of weighted indicators, user acceptance criteria, and a scoring mechanism that can be applied through field observation, physical condition measurement, and assessment of available facilities. Because the indicators used cover aspects of transfer efficiency, walking and waiting conditions, pedestrian circulation, and information provision, this instrument has the potential to be applied to various types of transit hubs connecting more than one transportation mode. Nevertheless, its application at other locations requires adjustment to the characteristics of each area, such as spatial configuration, the types of modes integrated, user volume, and operational conditions. The indicator weights produced in this study can be used as initial weights, while the assessment of physical conditions must still be carried out based on the characteristics of the location being evaluated. In addition, validation by experts or local users is still needed so that the instrument can more accurately describe actual conditions.

Nevertheless, this study still has several limitations that need to be considered in interpreting its results. Indicator weighting through the LAHP method was carried out with a limited number and characteristics of respondents, so that the results obtained more strongly represent the assessment of the expert group and selected respondents rather than all stakeholders. In addition, the user acceptance survey was only conducted on the transfer route between MRT Dukuh Atas Station and KRL Sudirman Station, so the results cannot be directly generalized to transit hubs with different physical characteristics, movement patterns, or service levels. This study has also not fully applied the instrument at multiple locations to test the consistency of the assessment results. Therefore, further research needs to carry out operational validation at various transit hubs with diverse characteristics, develop more detailed assessment guidelines in the form of a field audit checklist, and test the reliability of the instrument so that its use can support the process of evaluating and improving the quality of physical integration more broadly.

5. Conclusion

The research results show that the pedestrian physical integration of transit hubs can be evaluated through four main categories, namely walking distance and mode transfer time, walking and waiting conditions, pedestrian circulation, and information provision, which are broken down into 12 indicators. Weighting using the LAHP method shows that the walking distance and mode transfer time category is the most dominant aspect, with the indicators of mode transfer time, walking distance, and mobility assistance having the highest global weights. This finding confirms that intermodal transfer efficiency is the main factor in achieving good physical integration at transit hubs.

The criteria for each indicator were formulated through literature study and document study, then validated through a user acceptance survey. The survey results obtained a mean score of 4.19 on a 1-6 scale, with 11 out of 12 indicators significantly accepted above the neutral point. The walking distance indicator obtained the highest level of acceptance, while the real-time information board obtained the lowest level of acceptance and did not yet show statistical significance. The resulting evaluation instrument uses the global weight of each indicator, allowing it to provide a physical integration score while also helping to determine facility improvement priorities.

Priorities for transit hub development are directed toward improving mode transfer efficiency through the provision of mobility assistance facilities, clarity of pedestrian paths, reduction of circulation conflicts, and the provision of real-time information. This evaluation instrument also needs to be applied using measurable operational criteria so that assessment can be carried out consistently. Further research development can be carried out by expanding the number of expert respondents, testing the instrument at various transit hubs, and complementing the user survey with field observation, actual time measurement, and qualitative interviews to improve the validity of the instrument.

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