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Evaluating Accessibility and Comfort of Pedestrian Skybridges: An Observational and Physiological Approach

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ABSTRACT

This study evaluates the accessibility and psychological comfort of users on the skybridge connecting Tirtonadi Terminal and Solo Balapan Station. The research was conducted to assess the suitability of the facility for the needs of vulnerable groups, particularly people with disabilities and the elderly, who are often overlooked in pedestrian infrastructure design. A mixed-methods approach was applied through field observations, interviews with 10 users, and physiological stress measurements using galvanic skin response (GSR). The results of the analysis showed an average accessibility index value of 1.28 (categorized as less accessible), with several critical aspects—such as ramps, signs, ventilation, and lighting—not meeting standards. Furthermore, GSR data revealed an average 25% increase in stress, with 90% of respondents experiencing anxiety or distress when crossing the skybridge. These findings confirm that limited physical facilities directly impact users' psychological comfort. This study recommends the implementation of inclusive design based on PUPR standards, improvements to supporting facilities, and the integration of stress monitoring technology as part of the development of sustainable pedestrian infrastructure.

INTRODUCTION

Skybridges represent critical pedestrian infrastructure designed to enhance connectivity, safety, and mobility efficiency in densely populated urban environments. Beyond serving as grade-separated crossings that physically separate pedestrians from vehicular traffic, skybridges must embody universal accessibility principles to accommodate all population segments, including persons with disabilities, elderly users, and individuals with mobility limitations. However, extensive evidence from both national and international contexts reveals that numerous crossing facilities fail to meet established accessibility standards and user psychological comfort requirements, consequently diminishing utilization rates and potentially elevating pedestrian accident risks (Mashuri & Ikbal, 2011).

In Indonesia, pedestrian vulnerability remains critically high, as evidenced by 10,428 accident victims recorded in 2023, with 54.84% attributed to informal or undesignated road crossings. According to data from the Indonesian National Police Traffic Corps (Korlantas Polri), pedestrian fatalities constitute approximately 15% of total traffic accident deaths annually, with the majority occurring in urban areas with inadequate crossing infrastructure. This alarming statistic underscores the urgent need for safe, comfortable, and inclusive crossing infrastructure. Despite growing recognition of this issue, previous research has predominantly emphasized traffic safety dimensions while systematically neglecting comprehensive investigations into physical accessibility and psychological comfort, particularly for vulnerable population groups.

Pedestrian infrastructure is an important element in the transportation system, especially when it comes to road crossings, such as skybridges. Skybridge is one of the alternative crossings used by pedestrians, as it serves to provide a safe and efficient path in dense urban environments (Harahap, 2014). However, it is also important to ensure good accessibility and an optimal level of safety on the skybridge. Research by Deon Libora et al. (2023) shows that bridges can significantly reduce the number of pedestrian accidents and reduce traffic disruptions in the area, thus concluding that pedestrian bridges make a positive contribution to improving pedestrian safety (Libora & Indrastuti, 2023). Chiara Gruden et al. (2020) revealed that the density of pedestrian flow and the geometry of bridges have an important role in creating a safe or risky environment for pedestrians (Gruden et al., 2020).

Accessibility is the ability of any individual to acquire and use facilities or services without any barriers (Aljanzouri et al., 2014). In the context of skybridges, accessibility includes two aspects: physical accessibility and mental accessibility. Physical accessibility refers to the ease for all users, including people with disabilities and the elderly, to access and use the skybridge safely and comfortably. This includes ramps, stairs that are not too steep, and doors and corridors that are wide enough for wheelchair users (Bivina et al., 2019). Meanwhile, mental accessibility is related to the user's psychological comfort when using skybridge facilities, which is influenced by intuitive design, clear signage, and good lighting (Hadi & Yuono, 2023). Research by Daudi Katopola (2022) shows that many pedestrians are reluctant to use bridges because they feel safer or more comfortable crossing at ground level, although this increases the risk of accidents. Factors such as community involvement in bridge planning and design, as well as activities around bridges, have a significant influence on the level of use and effectiveness of bridges in improving safety (Katopola et al., 2022).

Multiple international studies have established the critical importance of accessibility in pedestrian infrastructure. Research by Bivina et al. (2019) in India identified that microscale environmental factors—including lighting quality, pathway smoothness, and directional clarity—significantly influence perceived walkability to transit stations. Similarly, Wu et al. (2023) demonstrated through multi-source urban data analysis that metro station accessibility directly correlates with ridership patterns and user satisfaction levels (Wu et al., 2023). In the Indonesian context, studies by Aji et al. (2022) on mosque accessibility and Rizki et al. (2024) on railway station infrastructure both confirmed systematic exclusion of users with reduced mobility due to inadequate facility design (Aji et al., 2022; Rizki et al., 2024). These findings collectively emphasize that optimal accessibility in skybridges is essential to ensure functional utility and effectiveness as transportation infrastructure (Isya & Chaisarina, 2021).

According to the Ministry of Public Works (2006), every public facility must meet four principles, namely safety, convenience, usability, and independence. These principles align with international standards established by the United Nations Convention on the Rights of Persons with Disabilities (UNCRPD), which Indonesia ratified in 2011, mandating accessible infrastructure as a fundamental human right rather than merely a design consideration.

Significantly, existing studies on pedestrian infrastructure evaluation predominantly measure technical compliance against design standards without considering users' physiological responses as indicators of psychological stress and burden. A critical research gap exists in integrating accessibility assessments with physiological stress indicators for holistic pedestrian infrastructure performance evaluation.

In addition, studies on pedestrian infrastructure evaluations generally only measure technical suitability against design standards, without considering the user's physiological response as an indicator of psychological stress and burden. In fact, physiological approaches—for example through Galvanic Skin Response (GSR)—are able to provide objective evidence regarding user comfort when interacting with the physical environment. Thus, there is a research gap in terms of integrating accessibility assessments with physiological stress indicators to evaluate the performance of pedestrian infrastructure holistically.

A number of studies have highlighted the importance of accessibility standards and psychological comfort in pedestrian infrastructure design. Research in Iran Zareharofteh & Eslami, (2021) emphasizes the importance of relaxation in using skybridges, making skybridge facilities standard and safe. Research Tian et al., (2022) in Japan explains the importance of paying attention to pedestrian interference in the design of crossing infrastructure because it reduces safety. Research Azouz & Fahim, (2022). in Egypt shows the importance of skybridge collaboration with stakeholders to achieve accessibility targets and support sustainable development. Then research Štimac Grandić et al., (2024). in Croatia highlights the importance of accessible skybridge design to encourage the use of pedestrian bridges and support sustainable active mobility. As well as best practices from different countries, such as optimal use of ramps, clear signage systems, adequate lighting, and good ventilation. However, studies on the relationship between the physical design of skybridges and the level of psychological stress of users are still limited, especially in the context of national cities such as Indonesia.

The skybridge connecting Solo Balapan Railway Station with Tirtonadi Terminal is designed to facilitate pedestrian mobility between the two locations, but since its trial, this skybridge has been minimally accessible to users, showing challenges in ensuring its optimal use and meeting the needs of all users including people with disabilities and the elderly (Dogan et al., 2019). Field findings show that some facilities in the skybridge are still considered inadequate, such as lighting that does not function properly, inadequate lighting, unstable temperatures, and designs that prioritize normal users without paying attention to the needs of people with disabilities (Suhardi et al., 2024). Therefore, public policy evaluation and ergonomic approaches are important to ensure that the skybridge is able to meet physical and mental accessibility aspects, by improving the layout, adjusting the dimensions of the facility, and adding supporting facilities in accordance with the provisions of PUPR Number 18/SE/Db/2023.

The use of checklist methods to assess physical accessibility and Galvanic Skin Response (GSR) measurements to measure user physiological stress aims to identify areas that have the potential to pose discomfort or risk, especially for vulnerable groups such as people with disabilities and the elderly (Markiewicz et al., 2022; Navea et al., 2019; Suhardi et al., 2023). The skybridge that connects Tirtonadi Terminal and Solo Balapan Station is one example of public facilities built to support multimodal mobility. However, since its operation, this facility has reportedly been underutilized, indicating design and user comfort issues. Therefore, a data-driven evaluation is needed to assess whether the skybridge has met the standards of actual (physical) accessibility as well as psychological (mental) comfort.

Based on these conditions, this study aims to evaluate the accessibility of skybridges using design parameters and technical regulations, measure user stress levels through physiological indicators (GSR), and identify the relationship between the quality of facility design and user psychological comfort. The results of the research are expected to be the basis for the development of an inclusive, sustainable, and user experience-oriented skybridge design.

METHOD

This research is explained through a flowchart that visualizes the steps taken during the research process, as shown in the following image.

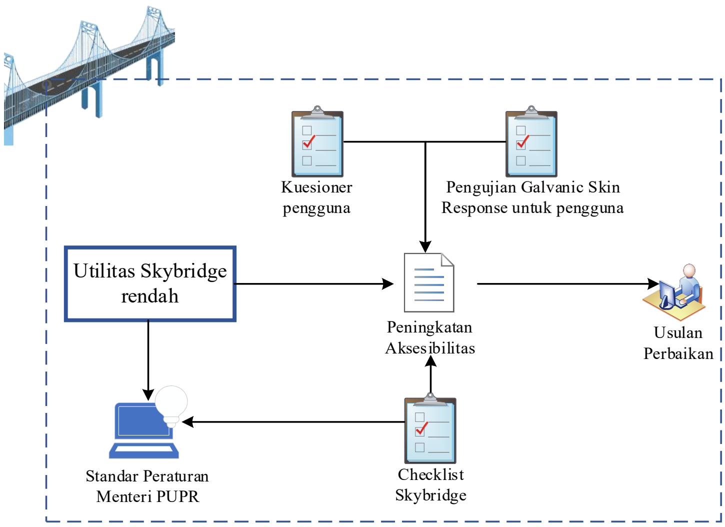

Figure 1. Research Flow Diagram

This study uses mixed-method approach (quantitative-qualitative) to evaluate the level of physical accessibility and psychological comfort of skybridge users connecting Tirtonadi Terminal and Solo Balapan Station. An observational approach is used to assess the facility's suitability against technical standards, while a physiological approach is used to measure the user's stress response through Galvanic Skin Response (GSR).

The research was carried out directly in the skybridge area as an intermodal connecting facility. Respondents were selected using the convenience sampling technique, namely users who are on site and willing to take part in observation and measurement. A total of 10 respondents were involved in the measurement of GSR, including users with limited mobility. The location of the research can be seen in Figure 2. Research Location.

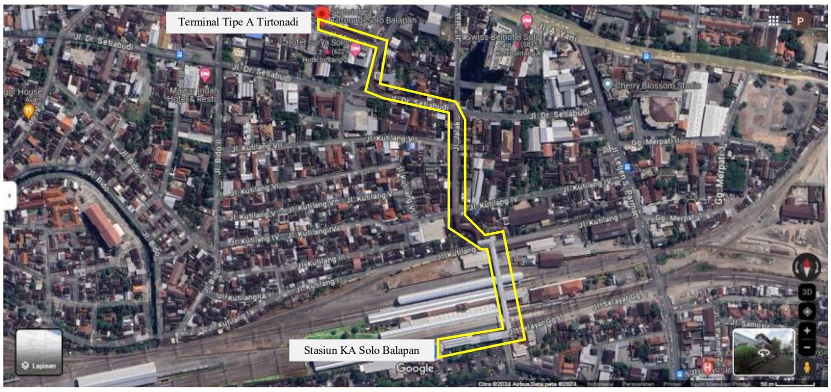

Figure 2. Research Location

The types of data collected include:

Table 1. Data Collection Techniques and Instruments

Data Type	Source	Instruments
Physical accessibility	Field observation	Checklist based on PUPR & PUPR Ministerial Regulation No. 14/2017 (Sianturi et al., 2023)
User perception & experience	Semi-structured interviews	Interview guide
Psychological comfort	GSR Measurement	Sensor GSR + laptop/recorder (Brocanelli, 2019)
Comparison data	Technical & regulatory documents	Literature, regulations, previous studies

The accessibility checklist includes 8 main aspects: access doors, elevators, ramps, escalators, stairs, corridors, signs & markings, and supporting facilities.

Data Processing Procedures

1. Observations are made to record the actual condition of the facility (dimensions, ramp slope, lighting, ventilation, signage, etc.).
2. Respondents were asked to walk along the skybridge while being subjected to a GSR sensor on their palms.
3. Electrodermal data is recorded to identify changes in skin conductivity as an indicator of stress.
4. Interviews were conducted after the GSR session to obtain subjective data on convenience, risk perception, and access barriers.

Data Processing and Analysis

1. **The accessibility index** is calculated based on a score of 0–2 per indicator with categories: 0 = not accessible, 1 = less accessible, 2 = accessible. The average index ≥ 2.5 is categorized as "accessible".
2. **Data GSR** analyzed by classification of skin conductance values: <2 mV relaxed, 2–4 mV calm, 4–6 mV anxious, >6 mV stress (Sianturi et al., 2023).
3. **Qualitative analysis** of the interviews was carried out with thematic coding to identify the factors causing the discomfort.

4. **Data triangulation** was carried out by comparing the results of observations, GSR, and interviews to ensure the consistency of findings.

Research Ethics

All respondents gave voluntary consent to participation. No sensitive personal data is collected, and all physiological measurements are carried out without causing any physical or psychological risk.

RESULT AND DISCUSSION

Accessibility is a crucial element in the development of public facilities, including skybridges designed to connect the two areas. Skybridges should be designed with the user's mobility space in mind, such as those who use wheelchairs, canes, or have other mobility limitations (Bivina et al., 2019). This accessibility assessment refers to the parameters set by the applicable law.

Skybridge Accessibility Index

The accessibility assessment was carried out using a checklist method based on PUPR standards and the Ministerial Regulation of PUPR No. 14/2017. Each aspect is scored 0–2, with the following categories: 0 = inaccessible, 1 = less accessible, 2 = accessible.

Each section is rated based on several indicators. If the criteria in these sub-aspects are met, a score of 2 (two) will be given for the accessible category. If the criteria are met but not in accordance with the applicable rules, so that they are considered less accessible, a score of 1 (one) will be given. If these sub-aspects do not meet the criteria or indicators set at all, a score of 0 (zero) will be given. The dimensions and completeness of skybridge facilities are adjusted to the implementation of the Regulation of the Minister of Public Works and Public Works Number 14 of 2017, which regulates accessibility in public buildings and facilities (Pekerjaan et al., 2022),(PUPR, 2023). Based on the assessment in the field, the results of the processing of the checklist sheet were obtained as follows.

Table 2. Skybridge Facility Accessibility Index Value Recapitulation

Facilities	Sub-aspects	Accessibility (A=2)	Less Accessibility (KA=1)	Inaccessible (TA=0)	Accessibility Index (IA)
Skybridge doors from the terminal	4	0	3	1	1.1
Skybridge door from the station	3	2	0	1	2.0
Skybridge lift from the station	6	0	5	1	1.3
Skybridge escalator from the station	2	0	2	0	1.5
Skybridge stairs from the station	2	2	0	0	3.0
Skybridge corridor	5	1	1	3	0.9
Ramp on the skybridge corridor	3	0	1	2	0.5

Facilities	Sub-aspects	Accessibility (A=2)	Less Accessibility (KA=1)	Inaccessible (TA=0)	Accessibility Index (IA)
Signs dan marks of skybridge	4	0	0	4	0.0
Total	29	5	12	12	10.28
Average	3.625	0.625	1.5	1.5	1.28

The results of the recapitulation are shown in Table 3. The average value of the accessibility index is 1.28, which is categorized as less accessible. The aspects with the lowest scores were signs and markings (0.0), corridor ramps (0.5), and main corridors (0.9), indicating a lack of facility support for users with disabilities, especially wheelchair users, the elderly, and individuals with reduced mobility. Aspects with relatively better accessibility are the stairs (3.0) and the access door of the station (2.0), but these two facilities cannot be fully utilized by users with physical limitations.

Physiological Stress Response (GSR)

GSR showed a link between changes in electrodermal activity and the emotional and physiological responses of skybridge users. GSR data measured through changes in skin conductance indicate that electrodermal activity increases significantly when skybridge users encounter stressful situations. On the other hand, in relaxed or neutral conditions, electrodermal activity tends to be stable with minimal fluctuations (Ouyang et al., 2023). The following are the results of GSR data processing from skybridge users.

Table 3. Galvanic Skin Response Data Recapitulation

They respond	Average GSR Response	Conditions
1	5,68	Anxious
2	4,56	Anxious
3	4,11	Anxious
4	4,07	Anxious
5	4,13	Anxious
6	4,91	Anxious
7	6,42	Stress
8	4,01	Anxious
9	4,35	Anxious
10	3,83	Calm down

GSR measurements were carried out on 10 respondents. Eight users showed an anxious response (4–6 mV), one user experienced stress (>6 mV), and only one respondent was in a calm state (<4 mV). The average GSR increase reaches 25% when passing through areas with low lighting, steep ramps, unclear signs, or confusing circulation facilities. This data shows that the limitations of physical design have a direct impact on the psychological comfort of the user.

Findings Integration

The study's key findings confirm the link between low accessibility and increased user stress. Two important outcome patterns are:

Table 4. Findings Integration

Physical Findings	User Response
Steep ramp, no handrails → score 0–1	GSR spikes and complaints of muscle tension
Minimal signage → score of 0	Confusion of direction, movement stopped, GSR rose significantly
Narrow & hot corridor → score of 0.9	Respondents reported "discomfort and fatigue quickly"
Elevators and escalators are not fully functional	Users with disabilities cannot cross independently

The Intersection of Accessibility and User Stress

The results show that physical barriers directly affect the psychological burden of users, especially in vulnerable groups. This is consistent with the findings of Katopola (2022) which states that users tend to avoid crossing bridges when their facilities cause insecurity or stress. The findings are reinforced by GSR data which shows the dominance of *anxiety* and *stress* conditions in most respondents, so that the aspect of mental comfort must be treated equally with the aspect of structural safety.

Non-compliance with Accessibility Standards

Ramp, signage, and ventilation facilities do not comply with the provisions of the Minister of Public Works and Public Works Regulation No. 14/2017, especially related to the maximum slope of the ramp (≤6°), the minimum width of the corridor, and the provision of handrails. This condition is similar to the research of Štimac Grandić (2024) which confirms that skybridge accessibility fails to be achieved when structural design does not take into account the needs of wheelchair users.

Implications of Inclusive Design

These findings suggest that the application of universal design is not yet optimal. Infrastructure that relies solely on stairs or automatic escalators cannot be categorized as accessible if it does not provide a safe alternative path for people with disabilities. In addition, the integration of physiological sensors such as GSR has the potential to become a design feedback tool in the development of public infrastructure based on user experience data (user-centered mobility infrastructure).

Research Contributions

This research reinforces the concept that accessibility is not only evaluated through physical parameters, but also through the user's physiological response. This observational + physiological hybrid approach provides added value compared to previous studies that only assessed conformity to technical standards.

CONCLUSION

This study reveals that the skybridge linking Tirtonadi Terminal and Solo Balapan Station falls short of universal accessibility and psychological comfort standards, with an accessibility index of 1.28 signaling poor performance in ramps, signs, and corridors; galvanic skin response (GSR) measurements further indicated that 90% of users experienced anxiety or stress due to user-unfriendly designs, underscoring a direct link between infrastructure quality and psychological burden, particularly for vulnerable groups like people with disabilities and the elderly. Theoretically, it advances pedestrian evaluation by integrating physical assessments with physiological stress indicators, while practically advocating for redesign per Permen PUPR No. 14/2017 and user comfort monitoring systems to foster inclusive public spaces—despite limitations in sample size and lack of comparative data. For future research, studies should expand to larger, diverse samples, compare multiple skybridges, and employ longitudinal wearable monitoring to capture dynamic stress changes, thereby enhancing human-centered infrastructure design.

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