

The TOPSIS Method Based on an Ergonomics Approach in Public Transportation in Surakarta to Support Local Economic Sustainability

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Abstract—In Surakarta City, high mobility is shown by 2023 vehicle registration data, where passenger cars and motorcycles made up 95,19% of all vehicles, while public transport units numbered only 354. In 2024, the city's economy grew by 5,61%, led by the Information and Communication sector. However, transportation did not contribute significantly, even though efficient public transport is crucial for sustainable urban growth. This study aims to recommend suitable public transportation modes for Surakarta that address mobility challenges and support integrates transportation ergonomics focusing on convenient, safety, accessibility and inclusivity into the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method to evaluate alternatives. Using a validated and reliable questionnaire distributed through purposive sampling, the study assessed several modes. The TOPSIS results show closeness coefficients of 0,847 for Batik Solo Trans (BST), 0,649 for taxis and motorcycle taxis, 0,593 for feeder minibuses, and 0,152 for pedicabs. BST emerged as the most suitable mode, offering potential to enhance mobility, streamline logistics, and attract investment. The findings highlight the importance of ergonomics-based transport policies that improve user experience and encourage a shift from private to public transportation, strengthening Surakarta's economic resilience.

Keywords: Ergonomics, Public, Selection, TOPSIS, Transportation

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1. Introduction

Public transportation is currently a key consideration in many developing and developed countries for the sustainability of social justice, as well as economic and environmental vitality [1]. Aligned with contemporary global policy frameworks, most notably the United Nations Sustainable Development Goals (SDGs), and informed by emerging discourses on sustainable urban mobility, public transportation has increasingly been recognized as a pivotal instrument in both developed and developing nations for promoting social equity, fostering economic resilience and ensuring environmental sustainability. In particular, in alignment with SDG 11 (Sustainable Cities and Communities), collaborative engagement with local communities serves as a strategic mechanism for advancing SDG targets by identifying context-specific mobility needs and co-developing inclusive solutions that support sustainable urban development [2]. The Indonesian government supports public mobility by improving public transportation services [3]. In Surakarta City, high mobility is reflected in motor vehicle registrations in 2023, the cars and motorcycles reaching 95,19% [4]. The number of public transportation vehicles reached 354 [5]. The economic growth depends on transportation policies and systems [6]. This research is a continuation of the researcher's thesis, which examined permanent bus stop facilities at the Batik Solo Trans (BST), which are not yet fully user-friendly especially for people with disabilities [7]. The BST shelters are not yet comfortable for people with disabilities, as the wheelchair maneuvering space is limited and the access ramps are excessively steep, thereby hindering independent mobility and safe access.

Surakarta city's economic growth in 2024 is projected at 5,61% with the information and communications business sector for the highest growth [8]. However, the local economic growth is influenced by decisions regarding the use of public transportation as a safe route for users mobility with cost and time efficiency [9]. In 2025, public transportation in Surakarta includes Batik Solo Trans (BST), feeder minibus, pedicab, taxi and motorcycle taxi.

Ergonomic Transport Design

Ergonomic bus seat design is necessary for passenger comfortable [10]. Without implementing ergonomic aspects, passengers with limited mobility are risk of musculoskeletal disorders [11]. Therefore, ergonomic design is needed to overcome these obstacles by providing solutions in the form of shifting from conventional systems to modern systems with digital equipment based on ergonomic theory [12]. This needs to provide a safer, more comfortable and environmentally friendly mode of transportation [13]. Previous research analyzed the bus shelter using SWOT method in accordance with PM Number 10 of 2012 to provide recommendations for user-friendly bus shelter designs [14].

Decision-Making Tools

This study utilizes the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) as the primary decision-making method. TOPSIS was selected because it assumes that the criteria are independent when applied to real-life situations. It is founded on the principle that the optimal alternative should be closest to the Positive Ideal Solution (PIS) while being farthest the Negative Ideal Solution (NIS) [15]. In contrast, fuzzy TOPSIS sets, characterized by membership functions ranging between zero and one, have been further extended to provide clear solutions for more complex decision-making problems [16]. The previous research used the Fuzzy TOPSIS method for process automation and AI integration in IoT network development to maximize its potential for resource management and increased efficiency towards the progress of smart cities [17]. Another research used the TOPSIS approach was selected to address the MOOP (Multi-Objective Optimization Problem) [18]. The existence of public transportation is often considered a vital element in creating a sustainable city from a social, economic and environmental perspectives [19].

Urban Sustainability

Developing urban transportation can improve the sustainability of the surrounding environment [20]. Transportation facilities contribute to the economic impact of the community [21]. Public transportation plays a crucial role in a city's economic growth by enhancing people's mobility, facilitating the distribution of goods and services, and encouraging investment [22]. However, limited research has addressed the inclusiveness and user-oriented aspects of transportation facilities, particularly for individuals with disabilities. Therefore, this study focuses on evaluating the accessibility and comfort of public transportation to promote more equitable and sustainable urban mobility.

Previous studies have explored various aspects of public transportation, including operational efficiency, service quality and environmental impact. However, many of these investigations have tended to emphasize technical or economic dimensions, with less attention given to how transportation infrastructure accommodates the comfort, safety and accessibility needs of diverse users. As cities continue to face growing demands for sustainable and inclusive mobility, there is a clear need for approaches that integrate human-centered design considerations into transportation evaluation and planning.

While past studies have primarily focused on the technical efficiency or economic implications of public transportation systems, limited attention has been given to the integration of user comfort and safety within the decision-making framework. Given the increasing urgency to develop transportation systems that are inclusive, user oriented and aligned with the principles of urban sustainability, this study introduces a novel integration of transportation ergonomics with the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method. The incorporation of ergonomic variables, particularly user comfort and safety, as core decision criteria distinguishes this approach from prior research and provides a timely framework for evaluating public transportation alternatives in Surakarta City. Through this integration, the study aims to support evidence-based decision making that enhances user experience, fosters local economic growth and contributes to sustainable urban development.

2. Method

Based on the problem of suboptimal public transportation choices in Surakarta City, an ergonomics-based approach using the TOPSIS method was applied to support local economic sustainability. TOPSIS is a multi-criteria decision-making method for selecting more effective alternative solutions [23]. This method ranks alternative solutions that minimize intellectual errors [24]. The weighting process and decision-making outcomes are conducted objectively and rely entirely on data without the influence of subjectivity [25].

In line with the ergonomic approach, which focuses on the comfort, safety and accessibility of public transportation users, it aims to improve the quality of transportation services to facilitate public mobility. Ergonomics involves designing with human limitations [26]. This method focuses on human factors and develops human-centered design [27]. Combining ergonomics and sustainability can help assess risks and improve human well-being to overcome an integrated manner [28]. The data used in this study were obtained from both primary and secondary sources. Primary data were collected through surveys and questionnaire distributed to 30 public transportation users with a purposive sampling technique using the criteria that users have used at least once in all public transportation modes in Surakarta.

In this research, the data collection instrument utilized a questionnaire developed based on the research indicators. The questionnaire was then tested using validity tests to ensure that each item accurately measures the intended variables and reliability tests to guarantee the consistency of the measurement results. A validity test is used to assess the accuracy of a measuring instrument in evaluating what it is intended to measure [29]. Reliability testing is a method used to determine the extent to which an instrument produces stable and consistent results. This testing is essential as it reflects the overall consistency of the instrument [30].

TOPSIS is a multi-criteria decision-making method used to determine the best alternative by comparing its proximity to the positive ideal solution (best solution) and negative ideal solution (worst solution). This method aims to select the alternative that is closest to the positive ideal solution and as far away as possible from the negative ideal solution.

The Decision Matrix is defined as an $m \times n$ array, in which m indicates the total number of alternatives and n is the total number of criteria. Each entry x_{ij} corresponds to the numerical score of alternative A_i with respect to criterion C_j , where $i = 1, 2, \dots, m$ and $j = 1, 2, \dots, n$.

$$X = \begin{matrix} & \begin{matrix} C_1 & C_2 & \dots & C_n \end{matrix} \\ \begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} & \begin{bmatrix} X_{11} & X_{12} & \dots & X_{1n} \\ X_{21} & X_{22} & \dots & X_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ X_{m1} & X_{m2} & \dots & X_{mn} \end{bmatrix} \end{matrix} \quad (1)$$

Decision Matrix Normalization: transforming the values within the decision matrix into comparable forms using normalization process so that all criteria have equal weight.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^m x_{ij}^2}} \quad (2)$$

Weigh Multiplication: a step that combines the normalized scores of each alternative with the corresponding criteria weights, which represent the relative importance of each criterion in the decision-making process.

$$y_{ij} = w_i r_{ij} \quad (3)$$

Determining Positive and Negative Ideal Solutions: the positive ideal solution refers to the alternative with the best value for each criterion, while the negative ideal solution refers to the alternative with the worst value for each criterion.

$$A^+ = \max (y_{1+}, y_{2+}, \dots, y_{n+}) \quad (4)$$

$$A^- = \min (y_{1-}, y_{2-}, \dots, y_{n-}) \quad (5)$$

Distance Measurement to the Ideal Solution: computing how far each alternative is from the positive and negative ideal solutions by applying formulas, for instance, the Euclidean norm.

$$D_i^+ = \sqrt{\sum_{j=1}^n (y_i^+ - y_{ij})^2} \quad (6)$$

$$D_i^- = \sqrt{\sum_{j=1}^n (y_{ij} - y_i^-)^2} \quad (7)$$

Determining the Degree of Closeness: the alternative that is closest to the positive ideal solution and farthest from the negative ideal solution is considered the best option.

$$v_i = \frac{D_i^-}{D_i^- + D_i^+} \quad (8)$$

Ranking of Alternatives: based on the closeness coefficient, alternatives are ranked and the one with the highest score is considered the best choice.

3. Result and Discussion

The application of weighting criteria based on their importance and ranking the most optimal transportation modes for the community using the TOPSIS method aims to select public transportation in Surakarta that will encourage local economic growth. The TOPSIS method works by comparing ergonomically-based alternatives against both positive and negative ideal solutions, making it easier to rank the best option based on community needs. The main advantage of TOPSIS is its ability to provide transparent and easy-to-understand results, considering multiple criteria simultaneously. It's reducing subjectivity and assists decision-makers in selecting optimal public transportation modes.

This research involved expert respondents, using a purposive sampling technique based on the criteria of public transportation passengers who had used all public transportation in Surakarta.

Validity Testing

This research involved 30 respondents to demonstrate how to properly conduct validity and reliability testing. The validity was statistically examined using the Pearson Product Moment (r). Table 1 shows that the questionnaire consisted of six items for the criteria. The data were then processed and analyzed using the Pearson Product Moment test to obtain the calculated r_{value} , which was compared to the r_{table} . The results indicated that all questionnaire items were valid, as the calculated $r_{\text{value}} > r_{\text{table}}$. This demonstrates that the questionnaire is effective in accurately measuring respondent knowledge.

Table 1. Validity Testing Results

Validity Testing	Question (Q)					
	Q1	Q2	Q3	Q4	Q5	Q6
r_{value}	0,978	0,962	0,933	0,961	0,937	0,964
r_{table}	0,361	0,361	0,361	0,361	0,361	0,361
Decision	Valid	Valid	Valid	Valid	Valid	Valid

Reliability Testing

The most commonly used reliability test is the Cronbach's Alpha coefficient. A good reliability test is recommended to have a Cronbach's Alpha value $> 0,6$. The reliability test results as shown in Table 2 indicate that the questionnaire developed by the researcher is reliable and consistent.

Table 2. Reliability Testing Results

Reliability Testing	Question (Q)					
	Q1	Q2	Q3	Q4	Q5	Q6
Variant	1,50	1,01	1,09	1,25	1,15	1,20
Number of Variant	7,20					
Total Variance	39,36					
Decision	0,981			Reliable		

Criteria Data

Table 3 shows that criteria variables are determined based on ergonomic aspects with achievement indicators that are relevant to the decision objectives.

Table 3. Criteria Data

Criteria (C)	Type of Criteria	Weight
Convenient User (C1)	Benefit	0,3
User Safety (C2)	Benefit	0,2
Accessibility and Inclusivity (C3)	Benefit	0,1
Fee (C4)	Cost	0,1
Time Efficiency (C5)	Benefit	0,2
Mobility (C6)	Benefit	0,1

This criteria data is collected and weighted according to the importance of each criterion to public transportation users. The criteria data analyzed using TOPSIS method, public transportation selection decisions based on ergonomic aspects can be evaluated and compared with the desired ideal solution, facilitating objective and measurable decision-making. The criteria weights used in the decision support system are obtained directly from experts through a user needs identification process. This ensures that the weights assigned reflect the actual needs to users and relevant to the objectives of public transportation selection, ensuring that the resulting decisions are appropriate and can provide recommendations for selected public transportation that can support local economic sustainability.

Alternative Assessment Data

Table 4 presents the alternative assessment data based on the criteria data in the context of selected public transportation that can support local economic sustainability based on ergonomic aspects. Data was obtained from respondents who met the specified criteria using a 1-5 likert scale. Calculated using Eq. (1). There are alternative modes of public transportation in Surakarta:

- A1 = Batik Solo Trans/BST;
- A2 = feeder minibus;
- A3 = pedicab;
- A4 = taxi and motorcycle taxi

Table 4. Alternative Assessment Data

Alternative (A)	Criteria (C)					
	C1	C2	C3	C4	C5	C6
A1	4,4	4,3	4,1	4	3,8	3,6
A2	4	3,4	3,4	4,1	3,6	3,2
A3	3,1	2,8	2,6	3	2,4	3,2
A4	3,7	3,9	3,2	3,3	3,8	4

Decision Matrix Normalization

Converting the values in the decision matrix into comparable scales through normalization, ensuring that all criteria are equally weighted as shown in table 5. Transforming the values in the decision matrix into comparable values by means of normalization in TOPSIS, calculated using Eq. (2).

Table 5. Normalization Results

Alternative (A)	Criteria (C)					
	C1	C2	C3	C4	C5	C6
A1	0,656	0,699	0,692	0,619	0,660	0,623
A2	0,596	0,552	0,574	0,634	0,625	0,553
A3	0,462	0,455	0,439	0,464	0,417	0,553
A4	0,552	0,634	0,540	0,510	0,660	0,692

Weight Multiplication

This step in the TOPSIS method is to combine the normalized value of each alternative with the weight of relevant criteria using Eq. (3). Table 6 presents the results of the weight multiplication of each alternative with the corresponding criteria weights, which represent the relative importance of each criterion. In this study, six ergonomics parameters were selected to evaluate public transportation modes in Surakarta, namely convenient user, user safety, accessibility and inclusivity, fee, time efficiency, mobility. These parameters were chosen based on their relevance to physical user experience and their frequent use in ergonomic standards. While other factors also be relevant, these six were prioritized for

their direct impact on the purpose is to ensure that user needs in terms of comfort, safety and ease of use have been considered from the early stages of decision making [31]. These ergonomics parameters were then integrated into the TOPSIS method to determine the most suitable public transportation mode in terms of both user comfort and local economic sustainability.

Table 6. Weight Multiplication Results

Alternative (A)	Criteria (C)					
	C1	C2	C3	C4	C5	C6
A1	0,197	0,140	0,069	0,062	0,132	0,062
A2	0,179	0,110	0,057	0,063	0,125	0,055
A3	0,139	0,091	0,044	0,046	0,083	0,055
A4	0,166	0,127	0,054	0,051	0,132	0,069

Positive and Negative Ideal Solutions

Table 7 presents the positive and negative ideal solutions to identify positive and negative ideal solutions for each criterion calculated using Eq. (4) and Eq. (5).

Table 7. Ideal Solutions Results

Ideal Solutions	Criteria (C)					
	C1	C2	C3	C4	C5	C6
A+	0,197	0,140	0,069	0,046	0,132	0,069
A-	0,139	0,091	0,044	0,063	0,083	0,055

Distance Measurement to the Ideal Solution

Table 8 presents the calculation of the positive ideal solution distance and the negative ideal solution distance, resulting in the positive dan negative ideal solution distance matrix calculated using Eq. (6) and Eq. (7).

Table 8. Distance Measurement to the Ideal Solution Results

Alternative (A)	D_i^+	D_i^-
A1	0,017	0,094
A2	0,043	0,063
A3	0,095	0,017
A4	0,037	0,069

Degree of Closeness

Table 9 presents the best option is the alternative positioned nearest to the positive ideal solution and farthest from the negative ideal solution calculated using Eq. (8).

Table 9. Degree of Closeness Results

Alternative (A)	v_i	Ranking
A1	0,847	1
A2	0,593	3
A3	0,152	4
A4	0,649	2

Based on the results of calculating using the TOPSIS method, the ranking of alternatives for public transportation modes is determined by the proximity value calculated from the distance of each alternative to the positive and negative ideal solutions. Alternative 1 (Batik Solo Trans/BST) is the highest proximity value of 0,847, indicating that this alternative is closest to the ideal solution. It was followed by alternative 4 (taxi and motorcycle taxi) in second choice with a proximity value of 0,649 which also performed well. Alternative 2 (feeder minibus) in third choice with a proximity value of 0,593, while alternative 3 (pedicab) ranked fourth with a proximity value of 0,152. The results of this study indicate that Batik Solo Trans (BST) emerged as the most preferred mode of public transportation when evaluated using ergonomic parameters and economic sustainability criteria. This finding aligns with previous studies emphasizing the importance of convenient user, user safety, accessibility and inclusivity, fee, time efficiency, mobility in influencing public transport choices in line with the

dynamics of the economy [32]. Similar research using the AHP TOPSIS method for transportation mode selection [33], yet they did not incorporate ergonomic considerations.

The integration of ergonomic principles with ergonomic sustainability objectives in this study extends previous literature by demonstrating that ergonomically optimized transportation modes not only enhance user experience but also promote modal shifts, alleviate congestion and contribute to local economic growth. However, beyond confirming the consistency of these results with earlier work, it is essential to interpret how these findings contribute to advancing knowledge in sustainable urban transport planning. The strong preference for BST suggests that ergonomic design improvements such as adequate passenger space, accessible boarding facilities and reduced physical strain, play a decisive role in shaping user satisfaction and willingness to use public transportation. This supports the argument that ergonomic quality should be treated as a core dimension of transport policy, complementing traditional economic and technical evaluations.

Furthermore, the findings highlight several implications for urban planning in Surakarta. The high ranking of BST demonstrates the effectiveness of large-capacity, structured transport systems in enhancing mobility efficiency, yet it also underscores the need to improve accessibility features, especially for people with disabilities. In contrast, the relatively low performance of non-motorized modes such as pedicabs indicates persistent challenges in integrating informal and sustainable transport into the broader mobility network. Future studies should examine how ergonomic interventions, such as improved station design, reduces physical barriers and better intermodal connectivity, can increase inclusivity and comfort for all users. By deepening the analysis of these aspects, this research contributes to the broader discourse on how human-centered approaches can inform sustainable transportation and urban development strategies in growing cities like Surakarta.

4. Conclusion

The selection of an appropriate public transportation mode is a critical determinant of sustainable local economic growth in Surakarta City. This study employed the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method using six ergonomically oriented criteria: user comfort, user safety, accessibility and inclusivity, fare, time efficiency, and mobility. The analysis revealed that Batik Solo Trans (BST) achieved the highest closeness coefficient (0,847), outperforming taxi and motorcycle taxi (0,649), feeder minibus (0,593) and pedicab (0,152). These findings highlight BST as the most optimal mode, demonstrating that the integration of ergonomic considerations into transportation evaluation not only enhances user experience but also contributes directly to sustainable mobility by promoting inclusive access, reducing travel-related fatigue and improving service efficiency. In turn, these factors strengthen economic resilience by fostering productivity and encouraging greater reliance on public transportation. Despite these promising findings, this study acknowledges several limitations. The analysis was constrained by the number of variables and the scope of data, which represented a specific temporal and spatial context. Unconsidered factors such as local government policies, post-pandemic mobility shifts, and advances in transport technology may have influenced user preferences and system performance. A more comprehensive approach incorporating these external dimensions would allow for a deeper understanding of the complex interactions shaping urban transport dynamics.

Future research should therefore expand the range of variables, extend the dataset over a longer observation period, and compare outcomes using alternative multi-criteria decision-making methods such as AHP or COPRAS. Further exploration of smart transportation technologies and data-driven planning tools could also enhance the precision and adaptability of mode selection framework. From a policy perspective, the findings suggest that embedding ergonomic design principles into urban transport planning can strengthen user satisfaction, equity and environmental sustainability, thereby providing actionable insights for municipal authorities seeking to advance the goals of inclusive and sustainable mobility in Surakarta City.

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