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Article

Determination of Factors for the Adoption ITS in Yogyakarta: Infrastructure, Technology and Policy Study

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Abstract: Rapid urbanization in developing cities like Yogyakarta has posed serious transportation challenges, including congestion, inefficient mobility, and environmental impacts. Intelligent Transportation Systems (ITS) offers innovative solutions by integrating technology into transportation infrastructure to improve urban mobility. However, the adoption rate of ITS in Yogyakarta is still low due to various obstacles, so further research is needed. This study aims to analyze the main factors influencing the adoption of ITS using a modified Technology Acceptance Model (TAM) model. The method used is a mixed-method approach, combining a quantitative survey of 300 respondents with expert validation to evaluate the impact of perception of usability (PU), perception of ease of use (PEOU), readiness of infrastructure, technology, socio-economic factors, and government policies. The proposed model integrates technology, infrastructure, and policy factors to evaluate their impact on ITS adoption. The dataset used includes user surveys and expert evaluations, which are then analyzed using Structural Equation Modeling (SEM-PLS) to validate the relationships between key variables. The results show that PU and PEOU play an important role in driving the adoption of ITS, while limited infrastructure and lack of government support are the main obstacles. In addition, low technological literacy and cost perception also contribute to public resistance to ITS. The proposed ITS adoption framework provides strategic insights for policymakers to address these challenges through infrastructure development, public awareness campaigns, and regulatory support, and can serve as a reference for other urban areas facing similar transportation problems.

Keywords: Intelligent Transportation System; ITS Adoption Framework; TAM; Perceived Usefulness; Smart Cities

1. Introduction

Transportation is a major factor in community mobility and has a significant impact on economic growth and the quality of life of the community [1]. However, challenges such as traffic jams, accidents, and unclear travel routes and directions have become problems that need to be addressed comprehensively [2]. The high rate of urbanization, especially in developing countries, further exacerbates congestion in urban areas, which can lead to economic losses of around 2–4% of Gross Domestic Product (GDP) [3–5]. Yogyakarta, as a medium-sized city, faces increasing transportation complexity due to a combination of growth in private vehicle ownership, inadequate public transportation infrastructure, and high tourism activity. Figure 1 show the Yogyakarta. The implementation of Intelligent Transportation Systems (ITS) in Yogyakarta is seen as an innovative solution to improve urban mobility, efficiency, and transportation sustainability [6,7]. ITS integrates Information and Communication Technology (ICT) into transportation infrastructure to create a smarter and adaptive system [8]. By utilizing real-time data from sensors installed in traffic infrastructure, ITS can help manage traffic more effectively based on vehicle density [9,10]. In addition, a real-time navigation system capable of providing accurate travel information can reduce travel time and improve the efficiency of vehicle movement [11,12]. The concept of smart mobility, which aims to improve connectivity between modes of transportation and reduce environmental impacts due to congestion, is also supported through the implementation of ITS [13].

Although ITS has great potential in improving transportation efficiency, its adoption rate in Indonesia, especially in Yogyakarta, is still relatively low due to various obstacles [14]. A number of studies have explored the benefits and application of ITS, especially in developed countries that have more established digital infrastructure. However, there is still a gap in understanding the main obstacles that hinder ITS adoption in developing cities such as Yogyakarta, where access to technology, differences in socioeconomic conditions, and policy support are still much different than in cities in developed countries. Many previous ITS implementation models failed to consider the unique challenges of medium-sized cities in Indonesia, such as the equitable distribution of digital infrastructure that is not optimal, varying levels of technological literacy, and government policies that are still limited in ITS regulations. Without overcoming these challenges, the success of ITS adoption in Yogyakarta is still uncertain.

Initial research has identified three main obstacles in the adoption of ITS in Yogyakarta. First, the limitations of technological infrastructure, where the Internet of Things (IoT) network and digital infrastructure are still uneven, especially in suburban areas, thus limiting the effectiveness of real-time data processing required for ITS operations [13]. These infrastructure limitations also lead to the low efficiency of smart mobility systems, which depend on the integration of advanced technology in urban transportation management [15].

Second, the level of technological literacy is diverse, where some people still do not understand the benefits of ITS so they are reluctant to adopt it. This has resulted in the low use of digital-based transportation solutions, such as intelligent navigation applications and automated traffic management systems [7]. As a result, people tend to remain dependent on conventional mobility methods, which slows down the transition to technology-based transportation [11].

Third, government policies are not comprehensive, where there are still limitations in regulations and incentives that support the implementation of ITS [8]. Studies show that successful adoption of ITS in various countries is often supported by a strong policy framework, including clear regulations regarding system interoperability as well as subsidies for ITS early adopters [6,16,17]. In Yogyakarta, the absence of regulations regulating data sharing standards, coordination between agencies, and incentives for transportation operators to switch to ITS-based systems are the main challenges in accelerating the adoption of this technology [18].

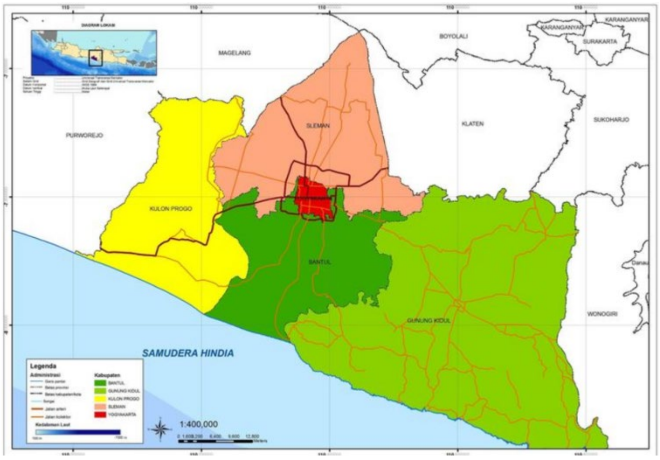


Figure 1. Yogyakarta Region.

To answer this gap, this study proposes a modification of the Technology Acceptance Model (TAM) to evaluate the factors influencing the adoption of ITS in Yogyakarta, focusing on Perceived Usefulness (PU), Perceived Ease of Use (PEOU), infrastructure readiness, socio-economic influence, and government policies. In contrast to previous studies that examined the feasibility of ITS technology in developed countries, this study aims to develop a more contextual and specific framework for urban transportation challenges in developing cities. The results of this study are expected to provide valuable insights for policymakers in designing strategic interventions to increase ITS adoption and improve urban mobility in Yogyakarta.

2. Literature Review

In this section, the literature review process is carried out using the PRISMA method, especially in the analysis and adoption of ITS in Yogyakarta. The literature review process in analyzing the ITS Framework Adoption process begins with the selection and screening process of articles carried out in this study. The PRISMA model is used to aid in the development of existing analyses.

The development of the Adoption Framework is taken as the main factor of the research based on the relevance of the existing, this can be seen in Figure 2. The process began with the identification of 390 articles, of which no duplicates were found. Furthermore, all 390 articles passed the initial screening stage, and as many as 323 articles were declared irrelevant based on the inclusion and exclusion criteria that had been set. A total of 67 full-text articles were then evaluated for feasibility. Of these, 14 articles were issued for the following reasons: 8 articles had different themes, 2 articles produced inappropriate outputs, 3 articles were in the form of literature studies, and 1 article was in the form of book chapters. After going through a strict selection process, as many as 53 articles were declared to meet the criteria to be included in the final analysis. This process can be seen in Figure 2. The basic development of the PRISMA process can be seen from the Bibliometric model seen in Figure 3.

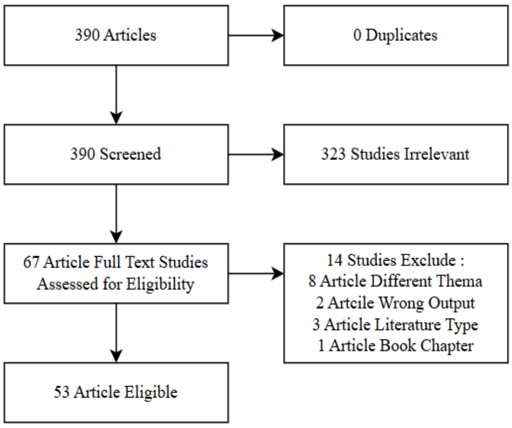


Figure 2. PRISMA Model for ITS.

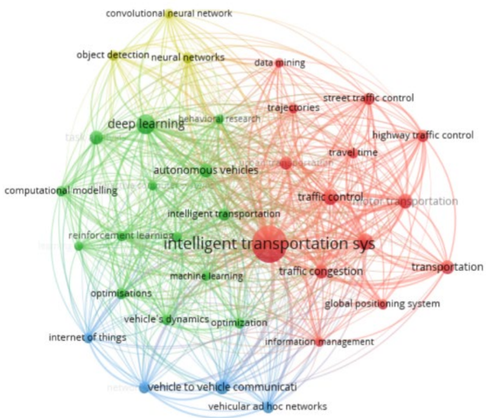


Figure 3. Bibliometric ITS Adoption.

2.1. Intelligent Transportation System

The adoption process of the Intelligent Transportation System (ITS) Framework refers to the application of information and communication technology (ICT) to improve the efficiency, safety, and sustainability of the transportation system [6]. The ITS framework includes the integration of systems across the board, where technologies such as adaptive traffic management, real-time navigation, and vehicle-to-infrastructure (V2I) communication are analyzed to determine their suitability for the existing region [16]. This technology enables a more dynamic transportation system by optimizing traffic flow and reducing travel time through more accurate data processing [10].

Despite its great potential, the adoption rate of ITS in developing countries such as Indonesia is still relatively low due to various challenges faced, including limited infrastructure, low technological literacy, and immature regulations [3,8]. One of the main obstacles is the lack of technological infrastructure that supports real-time data processing, such as 5G and IoT networks, which is needed to ensure the sustainability and reliability of the system [19]. In addition, low technological literacy among transportation users hinders the implementation of digital-based ITS solutions, which require user understanding in accessing traffic information and data-based navigation [7].

Regulations are also a key factor in the successful adoption of ITS. Countries with comprehensive ITS regulations tend to have higher adoption rates due to policy support and incentives for transport users and operators [13]. However, if the adoption of ITS is not carried out with the right approach and without coordination between the government, the private sector, and users, then there is a risk of failure in the implementation of this system, which can lead to inefficiency and waste of resources in the development of smart transportation infrastructure [11,16]

The success of the adoption of the ITS framework depends on a holistic approach, which not only focuses on technological aspects, but also includes infrastructure readiness, supporting policies, and community readiness to receive and use smart transportation technology optimally [20,21]. Table 1 below shows the causes of the failure to implement an ITS.

Table 1. Causes of Failure to Implement ITS.

No	Causes of Failure	Reference
1	Limitations of Technology Infrastructure	[8,18,22,23]
2	Lack of Supportive Regulations and Policies	[12,19,24]
3	Public Resistance to New Technologies	[23,25]
4	Limited Funds	[18,19,26–28]
5	Dependence on Technology that Wears Out Quickly	[20,29–31]
6	Lack of Collaboration between Stakeholders	[6,15,32,33]
7	Lack of Local Adaptation to Global Technology	[5,19]

2.2. Framework ITS Adoption

The adoption of Intelligent Transportation Systems (ITS) in various regions requires a systematic approach that considers a variety of key factors, including technology, infrastructure, socio-economy, and government policies [17,34,35]. The adoption framework provides conceptual guidance that helps understand the key elements that affect the adoption of technology by society and organizations [8]. These frameworks often refer to theoretical models such as the Technology Acceptance Model (TAM), which are then modified to suit local conditions, including the availability of digital infrastructure, transportation regulations, and user readiness to adopt new technologies [16,18,25].

The Technology Acceptance Model (TAM)-based Intelligent Transportation Systems (ITS) adoption framework can be an effective solution to understand the factors influencing the adoption of this technology in more depth [8,22].

2.3. TAM for ITS Adoption Model

In the context of Yogyakarta, the implementation of TAM can be adjusted to local factors such as technology affordability, public perception, and government policies [6]. Technological factors, such as network stability and infrastructure compatibility, play a crucial role in determining the success of ITS. In addition, public perception of ITS's efficiency in reducing congestion and improving transportation accessibility will greatly determine the level of adoption of this system [16]. The government also has a key role in forming regulations that support and provide incentives for ITS adoption to accelerate its implementation in Yogyakarta [8]. Research conducted by Abdullah et al. (2023) shows that PU and PEOU have a significant relationship with users' attitudes towards the adoption of ITS-based transportation systems, especially in relation to IoT infrastructure, real-time-based navigation, and more efficient transportation systems. External factors such as government support, technological literacy, and the reliability of communication networks also contribute to determining the level of ITS adoption in various regions [7,36].

Figure 4 illustrates the conceptual framework for the adoption of transportation technology based on the Technology Acceptance Model (TAM) which has been modified by incorporating various relevant factors. This framework describes the flow of relationships between external factors, user perceptions, and transportation technology adoption decisions, which overall play a role in the successful implementation of the ITS framework in a region [15].

Figure 5 illustrates the relationship between human factors, transportation systems, and other supporting elements in the transportation framework. This diagram shows that users are at the center of the transportation system and are influenced by four main factors: knowledge, habits, culture, and behaviour [18,22]. These factors play a crucial role in determining how users interact with transportation systems.

Information coming from the transportation system, known as transport information, serves as an important data source for users and transport authorities in supporting the decision-making process [7]. This information covers various aspects, including real-time traffic data, road infrastructure conditions, and safety factors, which overall contribute to the improvement of technological elements, safety, as well as the efficiency of the transportation system [10]. In the application of the Intelligent Transportation System (ITS), the optimal use of transportation data can produce a system that is more adaptive to road conditions and user needs [16].

The success factor of ITS reflects an integrated framework that aims to ensure the effective and efficient implementation of smart transportation systems [13]. The three main elements that form the main basis for ITS's success are:

1. Technology; Technology is the main foundation in ITS by providing digital devices that allow the system to work automatically and efficiently [10,20,37].
2. Infrastructure; Physical infrastructure is the main supporting element in the implementation of ITS. A good road network, adaptive traffic signal system, and data-driven traffic control center play a role in improving smooth mobility and reducing congestion [16]. The success of ITS is highly dependent on the integration between the existing transportation infrastructure and intelligent technology-based systems [12,38].
3. Socio-Economic Factors; Socio-economic aspects also contribute to the successful adoption of ITS [8,13,15].

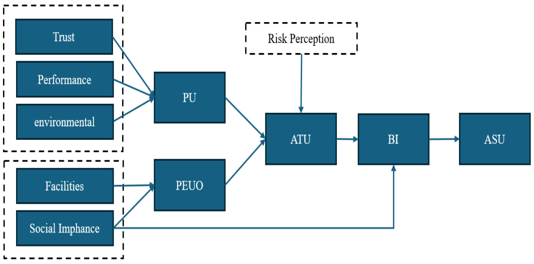


Figure 4. Framework for Risk Perception model [8].

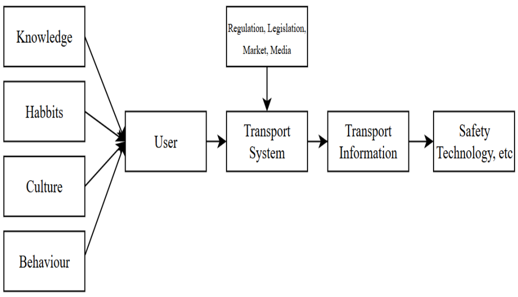


Figure 5. Coconceptual model for ITS Factor framework [39].

The success of ITS does not only depend on technological advancements, but also on the synergy between adequate infrastructure, supportive government regulations, and the readiness of the community to adopt new technology. With a holistic approach, smart transportation systems can operate optimally, improve mobility efficiency, and reduce the negative impact of transportation on the environment and economy.

3. Methodology

The methodology of this research consists of two main phases. Phase 1 includes a literature review using the PRISMA model, where 390 articles from reputable journals are screened up to 53 relevant articles selected for further analysis. The relevant literature is analyzed based on the research problem, research question, and research objectives, which then results in the first publication. Phase 2 focuses on identifying factors and variables that influence ITS adoption, covering technological, infrastructure, socio-economic, and policy aspects. The proposed factors are evaluated to ensure their suitability before being developed in the Technology Acceptance Model (TAM), with key variables such as Perceived Usefulness (PU), Perceived Ease of Use (PEOU), Behavioral Intention (BI), and Attitude Towards System Use (ASU). The model is then validated through factor analysis and hypothesis testing, resulting in the determination of dependent and independent variables that will be used in further research. The Methodology process can be seen in Figure 6.

This study uses a quantitative approach designed to identify the main factors affecting the adoption rate of ITS, examine the relationship between key variables, and provide strategic recommendations in the development of more effective technology-based transportation policies in urban areas with similar characteristics [16].

The population in this study consists of public transportation users, private vehicle users, and policy makers in the transportation sector. Yogyakarta City was chosen as the research location because of its characteristics as a tourism and education center that has complex transportation challenges and an urgent need for smart technology-based transportation solutions [20,40]. The sampling technique was carried out by stratified random sampling to ensure the proportional representation of various population groups. The sample size used in this study was 300 respondents, which was calculated based on Krejcie and Morgan (1970) calculations for a large population with an error rate of 5% [6]. Respondents were contacted through an online survey to collect data on ITS adoption factors, perceptions of smart transportation technology, and obstacles faced in its implementation.

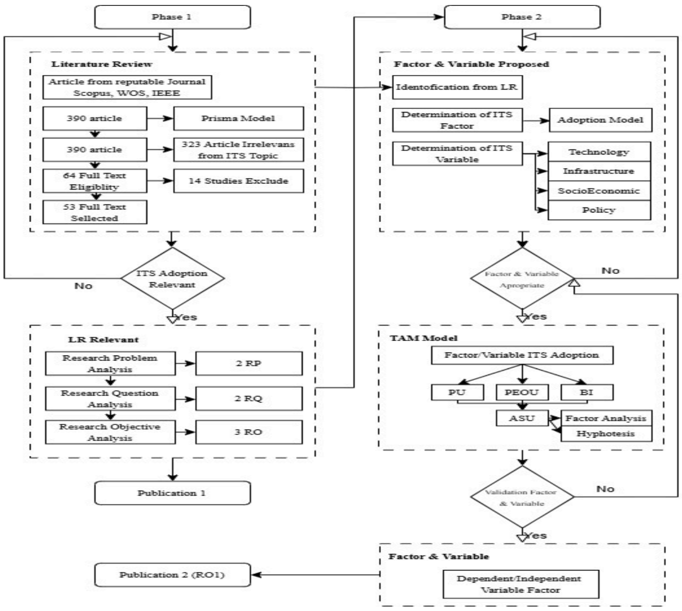


Figure 6. Methodology Process.

The survey instrument was developed based on a modified Technology Acceptance Model (TAM) model, measuring several key constructs [7,8,11]. To ensure the reliability and validity of the survey instrument, this study uses the Cronbach's Alpha reliability test [10,12]. The validity of the construct is tested through convergent validity, which uses Average Variance Extracted (AVE $\geq$ 0.50), as well as discriminatory validity, which uses the Fornell-Larcker Criterion to ensure that each construct has a higher correlation with its indicator compared to other constructs [10,13,16].

With a systematic methodological approach, this research is expected to make a significant contribution in understanding the factors influencing the adoption of ITS in developing cities as well as produce data-driven policy recommendations that can be used to improve the implementation of smart transportation systems in the future.

4. Result and Discussion

The study involved 300 respondents consisting of active ITS users (50%), prospective ITS users (50%). The majority of respondents were between 18 and 45 years old with secondary to tertiary education backgrounds. This distribution reflects the heterogeneity of Yogyakarta's population consisting of students, workers, and tourists. This heterogeneity is important to ensure the relevance of data to the needs of smart transportation in the region. It can be seen in Figure 7 the distribution of ITS users in Yogyakarta.

This study identifies various factors that affect the adoption of Intelligent Transportation Systems (ITS) in Yogyakarta, including perceived usefulness (PU), perceived ease of use (PEOU), infrastructure readiness, socio-economic factors, and government policy support. Model analysis using Structural Equation Modeling - Partial Least Squares (SEM-PLS) shows that the PU and PEOU variables have a significant impact on user intention in adopting ITS ($\beta = 0.72$, $p < 0.05$), which is consistent with previous findings in the Technology Acceptance Model (TAM) study [8].

However, this review is still lacking in comparing the results of ITS adoption in other developing countries that have similar urban characteristics to Yogyakarta. Several studies in developing countries, such as Jakarta (Indonesia), Bangkok (Thailand), and Ho Chi Minh City (Vietnam), have shown that regulatory factors and public-private partnerships play a key role in driving ITS adoption more effectively [12,18]. For example, in Bangkok, the integration between private and government companies in providing intelligent traffic management systems has accelerated the implementation of ITS and increased traffic efficiency by up to 30% [13]. Yogyakarta still faces challenges in terms of policy integration and infrastructure readiness, which sets it apart from other cities in developing countries that have managed to better adopt ITS.

In addition, although this study has identified various obstacles in the adoption of ITS, the recommendations provided are still general, such as infrastructure development and policy support. To provide a more actionable strategy for policymakers, here are some specific recommendations that can be implemented in the context of Yogyakarta:

1. Funding Model for ITS Development—The government can adopt a Public-Private Partnership (PPP) to finance the development of ITS infrastructure, such as those implemented in Singapore and South Korea, where this financing scheme has helped accelerate the digitalization of public transportation [19].
2. Public-Private Partnerships for Infrastructure Improvement—The establishment of partnerships with technology service providers and transportation operators can encourage the wider use of ITS technologies, such as real-time navigation systems and big data-driven route optimization (Big Data).
3. Public Awareness Campaign to Overcome Low Digital Literacy – An education program about the benefits of ITS can increase public understanding of this technology. In Vietnam, social media-based campaigns and incentives for the use of smart transportation have increased the adoption of e-ticketing systems by 40% in two years [16].

In addition to comparing the adoption factors of ITS with similar studies, it is important to highlight why these findings are relevant for Yogyakarta. For example, "adequate infrastructure supports ITS operations effectively" is an obvious finding, but in Yogyakarta, the main problem is not only limited to the lack of technological infrastructure, but also the inequality in the distribution of IoT networks and real-time data in suburban areas [7]. Without this equitable distribution of infrastructure, the benefits of ITS cannot be felt optimally by the entire population.

The results of the analysis of the structural model (inner model) show that each relationship between the main variables has a significant influence. Some of the key results are as follows:

1. Perceived Usefulness (PU) has a significant positive influence on user attitude (Attitude Toward Use, ATU) with a path coefficient of 0.72 ($p < 0.05$). This shows that the perception of ITS benefits, such as time efficiency and congestion reduction, is a major factor driving technology adoption.
2. Perceived Ease of Use (PEOU) also contributes significantly to PU with a path coefficient of 0.65 ($p < 0.05$), indicating that ease of use of technology plays an important role in improving the perception of ITS benefits.
3. Infrastructure factors (resource availability and network stability) showed a positive correlation with PU, with a line coefficient of 0.68 ($p < 0.05$). Adequate infrastructure supports ITS operations effectively.
4. Socioeconomic factors, such as cost perception and technological literacy, had a moderate influence on PEOU, with a pathway coefficient of 0.54 ($p < 0.05$). This shows that cost and understanding of technology are a challenge in ITS adoption.
5. Government policies have a significant effect on ATU with a track coefficient of 0.74 ($p < 0.05$). Appropriate regulations and incentives have been proven to increase public trust in ITS.

The results of this analysis confirm that the adoption of Intelligent Transportation Systems (ITS) in Yogyakarta is greatly influenced by public perception of the benefits of technology (Perceived Usefulness, PU) and its ease of use (Perceived Ease of Use, PEOU). This is consistent with the findings of Davis (1989), which shows that PU and PEOU are the two main predictors in the Technology Acceptance Model (TAM). In Yogyakarta, the main benefits of ITS that are most appreciated by the community are time efficiency and reduced congestion, especially in tourist areas such as Malioboro and other city centers, where traffic density levels are often high [16]. Figure 8 shows the factors influencing ITS adoption in Yogyakarta.

Infrastructure factors have also proven to play a crucial role in the successful implementation of ITS. Communication network stability and availability of Internet of Things (IoT) devices support reliable ITS operations [10]. Research Abdullah et al. (2022) shows that the availability of adequate technological infrastructure is the main prerequisite for the successful implementation of ITS, especially in developing countries such as Indonesia. However, this study also found that access to infrastructure in the suburbs of Yogyakarta is still limited, which is the main challenge in the equitable distribution of ITS implementation [7]. Therefore, investment in the development of inclusive digital infrastructure is important to ensure the sustainability and effectiveness of ITS. Figure 9 shows the key factors of the advantages of ITS adoption.

From a socioeconomic perspective, people's technological literacy is the main obstacle in the adoption of ITS. Research Alqubaysi dan Yousef (2024) It shows that people with low technological literacy tend to be reluctant to adopt new technology due to a lack of understanding of its benefits and skepticism about technological change. In the context of Yogyakarta, diverse technological literacy, especially among traditional transportation users and older age groups, is the main challenge in increasing ITS acceptance [15]. Therefore, public education programs and socialization of smart transportation technology need to be strengthened to increase awareness and acceptance of ITS.

Government policies have proven to be a major driving factor in the adoption of ITS. Support in the form of incentives for the use of ITS, setting interoperability standards, and regulatory supervision plays a role in increasing public trust in this technology [8]. Clear policies help ensure that smart transportation technologies can develop in a structured and sustainable manner.

In the context of Yogyakarta, synergy between local governments, transportation operators, and technology providers is the main key in ensuring the success of ITS [16]. For example, regulations related to the integration of digital ticketing systems, the development of electric vehicle networks, and incentive policies for transportation operators who implement ITS can accelerate the transition to a smarter and more efficient transportation system [13]. Figure 10 shows the challenges faced to implement ITS in Yogyakarta.

These results are also consistent with research Ahmed et al. (2022), which states that technology-based regulations can accelerate the implementation of smart transportation, especially in ensuring infrastructure sustainability and adoption by the community. These findings show that the TAM-based ITS adoption framework developed in this study can be implemented effectively. Validation using Structural Equation Modeling-Partial Least Squares (SEM-PLS) shows a significant relationship path between the perception of technology benefits, ease of use, infrastructure, and government policies on ITS adoption [10].

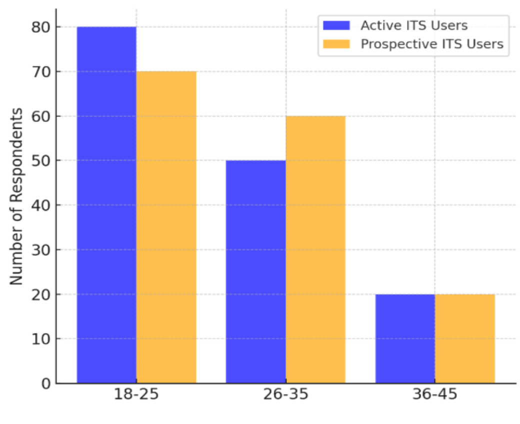


Figure 7. Active and Prospective ITS users.

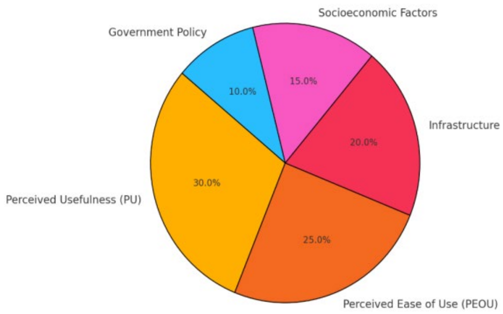
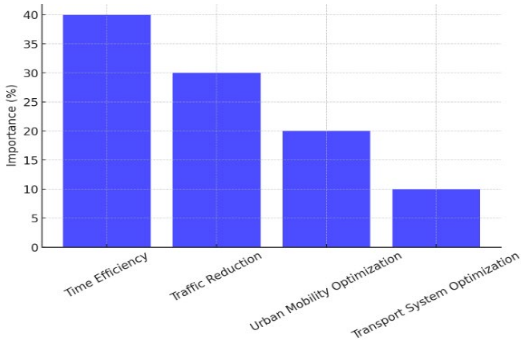


Figure 8. Factor influencing ITS Adoption in Yogyakarta.



Figurer 9. Key of Benefits Appreciated by Society.

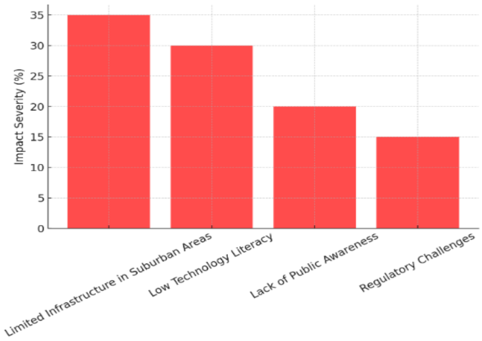


Figure 10. Challenges in ITS Implementation.

Some of the main paths that need to be strengthened in the ITS development strategy include :

1. Increasing the perception of the benefits of ITS technology by emphasizing the advantages of the system in reducing travel time, improving travel efficiency, and optimizing urban mobility [41,42].
2. Improve the perception of ease of use of ITS by ensuring an intuitive user interface, high accessibility, and wider public education [40,43].
3. Improve ITS supporting infrastructure, especially in the development of IoT networks and data communication stability for intelligent vehicles [44].
4. Strengthen government policies in providing incentives for ITS operators, develop standard regulations, and encourage collaboration with the private sector [18,38].

The overall results of this study contribute to the development of technology-based transportation policies, both in Yogyakarta and in other cities that face similar challenges in the implementation of ITS. Based on the ITS implementation success factor model proposed by [8,35,36,39], dan [21], then it can be seen the success factors of the implementation of ITS in Table 2 below.

Table 2. Review of ITS Factors from Researchers.

Factors	**Authors**				
	(*1)	**(*2)**	**(*3)**	**(*4)**	**(*5)**
Technology				√	
	√				
			√		
		√			
Infrastructure				√	
	√				
			√		
					√
		√			
Policy/Legislation				√	
			√		
					√
Social Economic				√	
			√		
		√			
					√
Knowledge / Information					√
	√				
Performance / Trust	√				
		√			
Environment			√		
					√

(*1): [8], (*2): [21], (*3): [35], (*4): [36[, (*5): [39].

Figure 11 above illustrates the Intelligent Transportation System (ITS) adoption framework based on a quantitative research approach. This diagram consists of three main parts, namely Proposed, Activity, and Result, which as a whole show how the key factors in ITS adoption are processed through quantitative research to produce a workable framework model.

1 Proposed: This section shows three main factors that contribute to the success of ITS, namely: Technology, includes the application of technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), and communication networks to improve the efficiency of transportation systems [10]; Infrastructure, involves the stability of transportation networks, the availability of ITS devices, as well as supporting systems such as adaptive traffic [16]; SocioEconomic, includes aspects of technological literacy, public acceptance of ITS, and cost factors that affect the sustainability of system implementation [24].

These three factors contribute to the success of ITS by influencing the adoption of technology and the effectiveness of its use in society.

2 Activity: The success factors of ITS were then analyzed using a quantitative research approach. In this approach, some of the key steps taken include : Measuring public perception of ITS using the Technology Acceptance Model (TAM), The analysis of the relationship between variables uses the SEM-PLS method, which aims to understand the extent to which technological, infrastructure, and socioeconomic factors affect the adoption of ITS [45], and Validasi model dengan partisipasi pemangku kebijakan dan pengguna ITS, guna memastikan framework yang dikembangkan sesuai dengan kebutuhan lokal [8].

3 Result: As a result of this study, the ITS framework model was developed based on the findings from quantitative analysis. This model is intended for : Becoming a guideline in the implementation of ITS in Yogyakarta and other regions with similar transportation conditions, Determine a significant path in the development of technology-based transportation policies, and Identify the most influential elements in driving ITS adoption, both from a technology, infrastructure, and socioeconomic perspective.

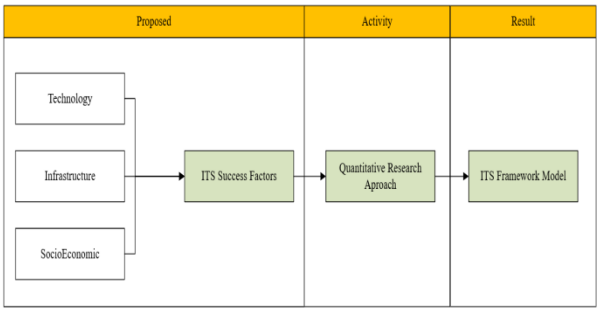


Figure 11. Proposed ITS Framework Model for Quantitative Approach.

The validation of this model ensures that the ITS implementation strategy can be implemented by considering the key factors that contribute to its success.

From a methodological perspective, this study also still does not present Model Fit Indices and R^2 Values, which is important to assess the extent to which this model can explain the variability in ITS adoption. Therefore, here is a table that summarizes the results of the model estimation:

From the Table 3, a value of SRMR = 0.056 indicates that the model has a good match with the data collected. In addition, the R^2 for the BI variable (0.70) shows that the model can account for 70% variability in the user's intention to adopt ITS, which is a strong indicator that the model can be used to predict the adoption factor of ITS in Yogyakarta.

Table 3. SEM-PLS Model Fit Index and R^2 Value.

Model Fit Index	Criteria Value	Model Results	Interpretation
SRMR (Standardized Root Mean Square Residual)	<0.08	0.056	The model has a good fit
NFI (Normed Fit Index)	>0.90	0.92	Model are acceptable
R^2—Perceived Usefulness (PU)	0.50–0.75	0.68	Model explains 68% of the variability of PU
R^2—Perceived Ease of Use (PEOU)	0.50–0.75	0.72	Model explains 72% variability of PEOU
R^2—Behavioral Intention (BI)	0.50–0.75	0.70	Model explains 70% variability in user intent in adoption ITS

The results of this study confirm that the perception of benefits and ease of use are the main factors in driving the adoption of ITS, while the main obstacles faced are infrastructure readiness, public awareness, and government policy support. Compared to other cities in developing countries that have successfully adopted ITS, Yogyakarta still needs a more targeted strategy in integrating ITS with existing transportation systems.

By implementing specific strategies such as the Public-Private Partnership (PPP)-based funding model, digital literacy education programs, and more proactive regulations in supporting the adoption of ITS, the government can accelerate the wider implementation of ITS and improve the efficiency of urban mobility. The SEM-PLS model used in this study also showed strong results in explaining the ITS adoption factors, with consistent R^2 values and model compatibility indices that met academic standards.

As a follow-up study, this study recommends a deeper exploration of the impact of economic incentives and user preferences on ITS, as well as a broader comparative study with other cities in developing countries that face similar challenges in ITS implementation.

5. Conclusion

Technology factors have proven to be a key element in driving the adoption of Intelligent Transportation System (ITS). Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) play a dominant role in increasing public acceptance of these technologies. The public perception that ITS can improve time efficiency and reduce congestion is the main motivation in its adoption [10].

Adequate infrastructure, such as IoT network stability and the availability of technological devices, are the main prerequisites for the successful implementation of ITS [7]. In this study, it was found that the availability of good infrastructure supports smooth communication between ITS components, thereby increasing the effectiveness of the intelligent transportation system [8].

Socioeconomic factors also play an important role in determining the adoption rate of ITS, especially in the aspects of technological literacy and cost perception [24].

Therefore, public education programs and public information campaigns need to be improved to increase awareness and acceptance of ITS. This campaign can be carried out through social media, public seminars, and the integration of ITS materials in the transportation and technology education curriculum.

Government policies have proven to be the main driving factor in accelerating the adoption of ITS. Supportive regulations, incentives for use, and supervision of the implementation of smart transportation technologies provide confidence to the public and increase adoption rates [13].

These results are in line with the findings of Ahmed et al. (2022) who emphasized that technology-based regulations can accelerate the implementation of smart transportation, especially in ensuring infrastructure sustainability and adoption by the community.

Although this research provides important insights into the adoption of ITS in Yogyakarta, some limitations need to be noted :

1. Limited area coverage : The research only focused on Yogyakarta, so the results may not be fully representative of other cities in Indonesia that have different transportation characteristics.
2. Focus on factors in TAM : This research focuses on PU and PEOU in TAM, while other factors such as the environment, local culture, and user behavior in the long term have not been explored in depth.

For this reason, future research is recommended to:

1. Expanding geographical coverage, so as to understand the variations in ITS adoption in different regions with different socio-economic and infrastructure conditions.
2. Exploring additional factors, such as environmental impact, sustainability policies, and aspects of local culture, in order to gain a more comprehensive understanding of ITS adoption.

Author Contributions

In this article, the lead author (H.H.) presents the research results according to the model and design developed. The second (A.H.) and third (N.B.) authors contribute conceptualization, methodological input and supervision of the results and outcomes produced.

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There is no conflict of interest in writing this article.

Data Availability Statement

Data collection can be obtained by contacting the main researcher, and can be provided according to mutual agreement. additional data is still in the process of authentication which will be used in the next research article.

References

1. F. Al-Turjman, "Smart-city medium access for smart mobility applications in Internet of Things," *Trans. Emerg. Telecommun. Technol.*, vol. 33, no. 8, 2022, doi: 10.1002/ett.3723.
2. B. Appleyard, W. Riggs, and J. Stanton, "Designing transportation and land use coordination: frameworks for measuring, understanding, and realizing sustainability, livability, and equity," *Local Environ.*, vol. 28, no. 5, pp. 564–579, 2023, doi: 10.1080/13549839.2022.2162026.
3. N. F. Abdullah, Y. C. Kiat, Y. Y. Sing, and R. Nordin, "Assisted Car Platooning and Congestion Control at Road Intersections," *Int. J. Integr. Eng.*, vol. 15, no. 5, pp. 286–293, 2023, doi: 10.30880/ijie.2023.15.05.030.
4. P. Agbaje, H. Olufowobi, S. Hounsinou, and G. Bloom, "From Weeping to Wailing: A Transitive Stealthy Bus-Off Attack," *IEEE Trans. Intell. Transp. Syst.*, vol. 25, no. 9, pp. 12066–12080, 2024, doi: 10.1109/TITS.2024.3377179.
5. M. S. Kumar and D. S. G. Krishnan, "Perceived Usefulness (Pu), Perceived Ease of Usekumar, M. S., & Krishnan, D. S. G. (2020). Perceived Usefulness (Pu), Perceived Ease of Use (Peou), and Behavioural Intension to Use (Biu): Mediating Effect of Attitude Toward Use (AU) with Reference to Mobi," *SSRN Electron. J.*, no. 933, pp. 933–941, 2020.
6. S.-P. Duarte, J. P. de Sousa, and J. F. de Sousa, "A conceptual framework for an integrated information system to enhance urban mobility," *Int. J. Decis. Support Syst. Technol.*, vol. 13, no. 4, pp. 33–49, 2021, doi: 10.4018/IJDSST.2021100103.
7. A. Feizi, S. Joo, V. Kwigizile, and J.-S. Oh, "A pervasive framework toward sustainability and smart-growth: Assessing multifaceted transportation performance measures for smart cities," *J. Transp. Heal.*, vol. 19, 2020, doi: 10.1016/j.jth.2020.100956.
8. W. Ahmed, S. M. Hizam, and I. Sentosa, "REVIEWING THE COMPONENTS OF TECHNOLOGY ACCEPTANCE BEHAVIOR IN TRANSPORTATION SECTOR," *Commun. - Sci. Lett. Univ. Žilina*, vol. 24, no. 3, pp. E96–E107, 2022, doi: 10.26552/com.C.2022.3.E96-E107.
9. K. Abrougui, A. Boukerche, and R. W. N. Pazzi, "Design and evaluation of context-aware and location-based service discovery protocols for vehicular networks," *IEEE Trans. Intell. Transp. Syst.*, vol. 12, no. 3, pp. 717–735, 2011, doi: 10.1109/TITS.2011.2159377.

10. Q. Chen, G. Pan, L. Zhao, J. Fan, W. Chen, and A. Zhang, "An Adaptive Hybrid Attention Based Convolutional Neural Net for Intelligent Transportation Object Recognition," *IEEE Trans. Intell. Transp. Syst.*, vol. 24, no. 7, pp. 7791–7801, 2023, doi: 10.1109/TITS.2022.3227245.
11. K. C. Dey, A. Mishra, and M. Chowdhury, "Potential of intelligent transportation systems in mitigating adverse weather impacts on road mobility: A review," *IEEE Trans. Intell. Transp. Syst.*, vol. 16, no. 3, pp. 1107–1119, 2015, doi: 10.1109/TITS.2014.2371455.
12. A. Choosakun and C. Yeom, "Developing evaluation framework for intelligent transport system on public transportation in bangkok metropolitan regions using fuzzy ahp," *Infrastructures*, vol. 6, no. 12, 2021, doi: 10.3390/infrastructures6120182.
13. A. Balasubramaniam, M. J. J. Gul, V. G. Menon, and A. Paul, "Blockchain For Intelligent Transport System," *IETE Tech. Rev. (Institution Electron. Telecommun. Eng. India)*, vol. 38, no. 4, pp. 438–449, 2021, doi: 10.1080/02564602.2020.1766385.
14. M. A. Alomrani, M. H. K. Tushar, and D. Kundur, "Detecting State of Charge False Reporting Attacks via Reinforcement Learning Approach," *IEEE Trans. Intell. Transp. Syst.*, vol. 24, no. 10, pp. 10467–10476, 2023, doi: 10.1109/TITS.2023.3281476.
15. H. Alawad, M. An, and S. Kaewunruen, "Utilizing an adaptive neuro-fuzzy inference system (ANFIS) for overcrowding level risk assessment in railway stations," *Appl. Sci.*, vol. 10, no. 15, 2020, doi: 10.3390/app10155156.
16. A. Arora and F. Belaïd, *Smart cities: Social and environmental challenges and opportunities for local authorities*. 2023.
17. A. Gohar and G. Nencioni, "The role of 5g technologies in a smart city: The case for intelligent transportation system," *Sustain.*, vol. 13, no. 9, pp. 1–24, 2021, doi: 10.3390/su13095188.
18. T. Nguyen, H. Nguyen, J. Partala, and S. Pirttikangas, "TrustedMaaS: Transforming trust and transparency Mobility-as-a-Service with blockchain," *Futur. Gener. Comput. Syst.*, vol. 149, pp. 606–621, 2023, doi: 10.1016/j.future.2023.08.011.
19. B. Ai, A. F. Molisch, M. Rupp, and Z.-D. Zhong, "5G key technologies for smart railways," *Proc. IEEE*, vol. 108, no. 6, pp. 856–893, 2020, doi: 10.1109/JPROC.2020.2988595
20. I. W. K. Suryawan *et al.*, "Smart urbanism, citizen-centric approaches and integrated environmental services in transit-oriented development in Jakarta, Indonesia," *Res. Glob.*, vol. 8, 2024, doi: 10.1016/j.resglo.2023.100181.
21. R. Dubey and A. Gunasekaran, "Sustainable transportation: An overview, framework and further research directions," *Int. J. Shipp. Transp. Logist.*, vol. 7, no. 6, pp. 695–718, 2015, doi: 10.1504/IJSTL.2015.072678.
22. Y. K. Dwivedi, N. P. Rana, A. Jeyaraj, M. Clement, and M. D. Williams, "Re-examining the Unified Theory of Acceptance and Use of Technology (UTAUT): Towards a Revised Theoretical Model," *Inf. Syst. Front.*, vol. 21, no. 3, pp. 719–734, 2019, doi: 10.1007/s10796-017-9774-y.
23. T.-H. Nguyen and J. J. Jung, "Swarm intelligence-based green optimization framework for sustainable transportation," *Sustain. Cities Soc.*, vol. 71, 2021, doi: 10.1016/j.scs.2021.102947.
24. T. Alqubaysi and A. Yousef, "Enhancing the driving experience of smart city users based on content delivery framework for intelligent transportation systems," *Sci. Rep.*, vol. 14, no. 1, 2024, doi: 10.1038/s41598-024-57065-3.
25. E. Rasoulinezhad and A. Akhavan, "Rethinking Russia's Economic Resilience against Western Sanctions: Model and Lessons for Iran's Economy," *Cent. Eurasia Stud.*, vol. 16, no. 2, pp. 124–148, 2024, doi: 10.22059/jcep.2024.358211.450143.
26. S. K. Jagatheesaperumal, S. E. Bibri, J. Huang, J. Rajapandian, and B. Parthiban, "Artificial intelligence of things for smart cities: advanced solutions for enhancing transportation safety," *Comput. Urban Sci.*, vol. 4, no. 1, 2024, doi: 10.1007/s43762-024-00120-6.
27. A. Hajimirzajan, M. Vahdat, A. Sadegheih, E. Shadkam, and H. E. Bilali, "An integrated strategic framework for large-scale crop planning: sustainable climate-smart crop planning and agri-food supply chain management," *Sustain. Prod. Consum.*, vol. 26, pp. 709–732, 2021, doi: 10.1016/j.spc.2020.12.016.
28. Y. Sun, Y. Hu, H. Zhang, H. Chen, and F.-Y. Wang, "A Parallel Emission Regulatory Framework for Intelligent Transportation Systems and Smart Cities," *IEEE Trans. Intell. Veh.*, vol. 8, no. 2, pp. 1017–1020, 2023, doi: 10.1109/TIV.2023.3246045.
29. A. Montazeri *et al.*, "A novel AI-based approach for modelling the fate, transportation and prediction of chromium in rivers and agricultural crops: A case study in Iran," *Ecotoxicol. Environ. Saf.*, vol. 263, 2023, doi: 10.1016/j.ecoenv.2023.115269.
30. T. O. Alshammari, "Smart pedestrian network is an approach for promoting walkability: A case of Riyadh city," *Period. Eng. Nat. Sci.*, vol. 10, no. 4, pp. 40–56, 2022, doi: 10.21533/pen.v10i4.2975.
31. M.-T. Lu, H.-P. Lu, and C.-S. Chen, "Exploring the Key Priority Development Projects of Smart Transportation for Sustainability: Using Kano Model," *Sustain.*, vol. 14, no. 15, 2022, doi: 10.3390/su14159319.
32. K. W. Wong, K. S. Khor, and S. T. Homer, "Perception of smart sustainable cities: a conceptual framework development using group concept mapping method," *Asia-Pacific J. Reg. Sci.*, vol. 7, no. 3, pp. 959–985, 2023, doi: 10.1007/s41685-023-00293-8.
33. H. M. A. Farid, S. Dabic-Miletic, M. Riaz, V. Simic, and D. Pamucar, "Prioritization of sustainable approaches for smart waste management of automotive fuel cells of road freight vehicles using the q-rung orthopair fuzzy CRITIC-EDAS method," *Inf. Sci. (Ny).*, vol. 661, 2024, doi: 10.1016/j.ins.2024.120162.
34. W. George and T. Al-Ansari, "GM-Ledger: Blockchain-Based Certificate Authentication for International Food Trade," *Foods*, vol. 12, no. 21, 2023, doi: 10.3390/foods12213914.
35. R. K. C. Billones, M. A. Guillermo, K. C. Lucas, M. D. Era, E. P. Dadios, and A. M. Fillone, "Smart region mobility framework," *Sustain.*, vol. 13, no. 11, 2021, doi: 10.3390/su13116366.

36. X. Han *et al.*, "Foundation Intelligence for Smart Infrastructure Services in Transportation 5.0," *IEEE Trans. Intell. Veh.*, vol. 9, no. 1, pp. 39–47, 2024, doi: 10.1109/TIV.2023.3349324.
37. H. Auvinen and A. Tuominen, "Future transport systems: Long-term visions and socio-technical transitions," *Eur. Transp. Res. Rev.*, vol. 6, no. 3, pp. 343–354, 2014, doi: 10.1007/s12544-014-0135-3.
38. Z. Lv, R. Lou, and A. K. Singh, "AI Empowered Communication Systems for Intelligent Transportation Systems," *IEEE Trans. Intell. Transp. Syst.*, vol. 22, no. 7, pp. 4579–4587, 2021, doi: 10.1109/TITS.2020.3017183.
39. C. Wang, F. Yin, Y. Zhao, and L. Yin, "Making Transportation Systems in U.S. Cities Smarter and More Inclusive: A Synthesis of Challenges and Evaluation of Strategies," *ISPRS Int. J. Geo-Information*, vol. 12, no. 2, 2023, doi: 10.3390/ijgi12020072.
40. M. Adhikari, A. Hazra, V. G. Menon, B. K. Chaurasia, and S. Mumtaz, "A Roadmap of Next-Generation Wireless Technology for 6G-Enabled Vehicular Networks," *IEEE Internet Things Mag.*, vol. 4, no. 4, pp. 79–85, 2021, doi: 10.1109/IOTM.001.2100075.
41. K. M. Almatar, "Smart transportation planning and its challenges in the Kingdom of Saudi Arabia," *Sustain. Futur.*, vol. 8, 2024, doi: 10.1016/j.sftr.2024.100238.
42. G. B. A. Wicaksana, "Future City Based on Smart Mobility Concept: Character and Benchmarking," *J. Archit. Res. Educ.*, vol. 2, no. 1, p. 10, 2020, doi: 10.17509/jare.v2i1.24112.
43. D. Naudts *et al.*, "Vehicular communication management framework: A flexible hybrid connectivity platform for CCAM services," *Futur. Internet*, vol. 13, no. 3, 2021, doi: 10.3390/fi13030081.
44. C. Garau, G. Desogus, B. Barabino, and M. Coni, "Accessibility and Public Transport Mobility for a Smart(er) Island: Evidence from Sardinia (Italy)," *Sustain. Cities Soc.*, vol. 87, 2022, doi: 10.1016/j.scs.2022.104145.
45. N. Abdullah et al., "Integrated Approach to Achieve a Sustainable Organic Waste Management System in Saudi Arabia," *Foods*, vol. 11, no. 9, 2022, doi: 10.3390/foods11091214