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Challenges to sustainable transport infrastructure integration in Johannesburg, South Africa

Ntebo Ngcobo *, Opeoluwa Akinradewo **, Phindile Mokoena ***

** Department of Civil Engineering Technology, University of Johannesburg, Johannesburg, South Africa*
ntebon@uj.ac.za
*** Department of Quantity Surveying and Construction Management, Faculty of Natural and Agricultural Sciences, University of the Free State, Bloemfontein, South Africa*
opeakinradewo@gmail.com
**** Department of Civil Engineering Technology, University of Johannesburg, Johannesburg, South Africa*
phindilemokoena020@gmail.com

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Abstract: *Purpose*. This study assesses the challenges of incorporating sustainability into South Africa's transport infrastructure, focusing on Johannesburg. *Methodology*. A quantitative approach was employed, using closed-ended questionnaires distributed to professionals involved in road infrastructure delivery and construction in South Africa. Data were analyzed using Mean Item Score (MIS) and factor analysis. *Results*. Key challenges identified include lack of political commitment to sustainable transportation, insufficient investment in energy-efficient vehicles, and resource constraints. The study also highlighted the need to expand and modernize transport infrastructure to accommodate population growth and increased economic activities. *Theoretical contribution*. This research provides insights into the specific barriers to sustainable transport infrastructure development in an urban South African context. *Practical implications*. The findings underscore the importance of improved coordination among government entities, private sector participants, and communities to address challenges and achieve sustainable transport infrastructure development.

Keywords: economic development, infrastructure modernisation, sustainable transportation, urban planning

Sustainable Development Goals (SDGs): SDG 11: Sustainable Cities and Communities; **SDG 9:** Industry, Innovation and Infrastructure**; SDG 13:** Climate Action; **SDG 7:** Affordable and Clean Energy; **SDG 3:** Good Health and Well-being

Corresponding author: *Opeoluwa Akinradewo*
E-mail: opeakinradewo@gmail.com

1. Introduction

Transport infrastructure plays a crucial role in the economic development of regions and cities, with various modes of transportation offering distinct advantages and drawbacks. The road-transport system, being highly flexible and cost-effective, provides door-to-door services and frequent itineraries, enhancing user convenience and efficient short-distance transport. However, it is associated with elevated long-distance transportation costs and maintenance expenditures (Castanho et al., 2020). On the other hand, rail-transport infrastructures offer low transportation costs, safety, comfort, and mass transit potential but lack the flexibility of road transport due to rail-dependent movements and planned itineraries (Abdulkadr et al., 2022). Maritime infrastructures excel in low-cost, long-distance transportation and carrying bulky commodities but are limited by low speed, flexibility in rerouting, and inability to serve land areas (Yasir et al., 2022). Air-transport infrastructures are crucial for regional development due to their speed but are challenged by high transportation costs, limited bulk cargo movement, and minimal flexibility owing to scheduled routes (Fang et al., 2022).

Sustainability in transportation infrastructure is a growing concern, with researchers emphasizing the need to minimize environmental impact while enhancing social needs (Badassa et al., 2020). Accessibility to transportation is considered a priority for public transportation, especially in developing nations, where concerns about the condition of public transportation systems have escalated (Lu et al., 2022; Okoro & Lawani, 2022) have proposed ways to improve sustainability in transportation, highlighting the potential for building out non-motorized transportation infrastructure alongside public transportation improvements (Okoro & Lawani, 2022). Non-motorized transportation is essential for achieving sustainable and economically effective transport systems (Okoro & Lawani, 2022). Additionally, urban supply chain management includes urban transportation as a critical component, emphasizing the importance of researching cutting-edge methods and techniques for benchmarking in urban transportation initiatives (Wang, 2021).

Johannesburg, located in the Gauteng Province of South Africa, faces significant challenges in incorporating sustainability into its transport infrastructure. The city's comprehensive public transportation system, comprising road and train routes, is under pressure due to the increasing population and the resulting high demand for transportation. The primary threat to metropolitan areas like Johannesburg is the expected increase in road traffic levels, which reduces the feasibility of public transportation and negatively impacts accessibility (Chkhirodze, 2021). This increase in road traffic also leads to the emission of greenhouse gases, contributing to environmental degradation and climate change. Transportation significantly contributes to greenhouse gas emissions, noise pollution, and climate change, accounting for approximately 15% of total greenhouse gas emissions and 22% of carbon dioxide emissions. In 2013, the transport sector accounted for 23% of global emissions, with road transport emissions contributing 75%, indicating a significant environmental impact. South Africa, particularly Johannesburg, has been identified as the continent's most significant energy consumer and the leading emitter of greenhouse gases due to transportation compared to other countries.

The challenges facing incorporating sustainability into Johannesburg's transport infrastructure are multifaceted. These challenges include the need to develop an appropriate environmental, economic, and social development strategy for sustainable transport, reducing the negative impact of traffic on air quality, increasing awareness of the population about air quality, and controlling vehicle flow to mitigate the adverse effects on air quality (Chkhirodze, 2021). Additionally, the city must work on updating the vehicle fleet, creating electric transport infrastructure, and implementing appropriate planning for green cover cultivation to address the environmental impact of transportation (Chkhirodze, 2021).

Furthermore, the city needs to optimize traffic management, set age limits on imported cars, tighten fuel quality and emission requirements, and introduce mandatory use of catalytic converters to reduce emissions (Chkhirodze, 2021). These challenges highlight the complex and interconnected nature of incorporating sustainability into the existing transport infrastructure of Johannesburg, encompassing environmental, economic, and social dimensions. Therefore, there is a need to assess the challenges of incorporating sustainability into the existing transport infrastructure of Johannesburg. Hence, the objective of this study is to assess the challenges of incorporating sustainability into South Africa's transport infrastructure, focusing on Johannesburg. Addressing these challenges requires a comprehensive approach that considers environmental, economic, and social factors to mitigate the negative impact of transportation on air quality, greenhouse gas emissions, and overall environmental sustainability.

2. Transportation infrastructure in South Africa

With major highways like the N1, N3, and N12 connecting the city to various regions of South Africa, Johannesburg boasts a vast road network. Additionally, the city boasts a sophisticated network of avenues, streets, and arterial roads (SANRAL). The way that the country's economy develops is significantly impacted by transportation. The public's standard of living is raised by road infrastructure and all transportation services that rely on it, including private automobiles, public transportation, and goods transporters (Hlatshwayi et al., 2024). These services also facilitate business interaction, serve a social purpose, and help governments foster economic development (Rensburg and Krygsman, 2020). In addition, governments have consistently reacted favorably to this correlation between wealth and roads, making significant investments in the latter. This is an accomplishment given that South Africa is the 25th largest country by area, has a GDP per capita ranked 86th in the world and is categorized as a middle-high-income country.

A well-maintained transportation infrastructure raises a nation's potential for production by facilitating the mobilization and productivity of its available resources, claim Pradhan and Bagchi (2013). However, by changing aggregate demand, transportation infrastructure can also affect economic growth. Building transportation infrastructure, for instance, can create and increase demand for intermediate inputs from other industries, causing the economy to experience multiplier effects. Despite being the smallest province in the nation, Gauteng has a larger population because it offers more options for employment, education, and leisure. The increasing population has an adverse effect on Johannesburg's traffic flow, ultimately undermining sustainable development's objective. The city has minibusses, Gautrain, and BRT as public transportation accessible to everyone in the city.

2.1. Sustainability

At the United Nations (UN) Conference on the Human Environment in Stockholm in 1972—the first international symposium devoted only to environmental issues—the concept of sustainability was first presented (Bueno, Vassallo, and Cheung, 2015). Sustainability is "development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs", according to the UN World Commission on Environmental and Development's 1987 definition.

The three pillars of sustainable development are social, environmental, and economic sustainability. These three interrelated pillars of sustainability serve as a framework for creating transportation systems that balance social justice, economic prosperity, and environmental stewardship. Transportation sustainability necessitates a comprehensive strategy that considers all three aspects at once (Kumar and Anbanandam, 2022). Encouraging people to switch from driving their cars to using public transportation should always aim to promote a system of transportation that maximizes benefits and minimizes drawbacks in terms of time, cost, environmental impact, societal implications, and economic factors. This system may involve more than one mode of transportation (Redman et al., 2013).

2.1.1. Social sustainability

The first area of unmet knowledge is social sustainability in transportation. According to Zhao (2012), social justice, freedom, community liveability, safety, health, values, beliefs, dignity, and societal perspectives are all included in a narrow definition of social sustainability. Similarly, Wey (2019) claimed that social sustainability in transportation prioritizes people's health and standard of living. It covers topics including safety, equity, accessibility, and the social effects of transportation networks on underprivileged groups and communities. Access to employment and social opportunities within the social context is undoubtedly provided by transportation. Accessibility is equally essential because the primary purpose of transportation is to move people, as well as goods and services, from one place to another (Kumar and Anbanandam, 2022). Adequate transportation also reduces time wastage, guarantees commuter safety, enhances societal health, and raises the standard of living. Most importantly, companies or people cannot profit at the expense of others, especially underprivileged groups or individuals, for transportation to be socially sustainable (Stefaniec et al., 2021).

2.1.2. Environmental sustainability

The goal of environmental sustainability in transportation is to reduce the harmful effects that transportation networks have on the environment. Reducing greenhouse gas emissions, noise pollution, air pollution, and resource depletion are all part of this. Haider et al. (2021) stated that Road-based modes of transportation have the potential to significantly contribute to environmental issues like air pollution and climate change if they produce high levels of CO2 emissions. Tran, Yang, and Huang (2021) state that a sustainable transportation system should operate in an environmentally sensitive manner by keeping waste, pollutants, and noise levels within the bounds of the Earth's ecosystem and by using as few scarce resources as possible. On the other hand, transportation can result in increased urban sustainability if, for instance, traffic-reduction programs can lower a city's metabolism of liquid fuel use (Hlastshwayo et al., 2024). Ultimately, the infrastructure built for transportation, especially public transportation, can have profound symbolic and cultural effects. It can foster significant societal divisions or catalyse people to unite in shared public spaces (Wray et al., 2014).

2.1.3. Economic sustainability

For both national and urban systems to function appropriately, transportation is essential. Ensuring the effective use of resources and the long-term financial sustainability of transportation networks are the main goals of economic sustainability in transportation. It considers financial stability, economic benefits, and cost-effectiveness (Litman, 2019). Different modes of transportation compete and collaborate when it comes to enabling the flow of people and products within the economic spaces of cities and countries (Mitullah & Vanderschuren, 2017). Developing countries lack formal public transportation systems to meet the entire mobility demand within cities, given the diverse socioeconomic needs of the population, as a result of rapid urban expansion, an annual motorization rate exceeding 10%, and a lack of comprehensive urban planning (Felix & Mohareb, 2017). Furthermore, coupled with deficiencies in street design that do not always account for user behavior, this issue has led to the inevitable emergence of informal public transportation modes that primarily prioritize the economic considerations of users, often at the expense of other aspects.

2.2. Challenges of Incorporating sustainability into the transportation infrastructure

In many nations, incorporating sustainable concepts into the planning and construction of transportation infrastructure projects has become increasingly popular. A project for sustainable road transportation has been designed and carried out with a degree of sustainability that significantly exceeds the already-used traditional methods (Tran, Yang, and Huang, 2021). The cities' expanding populations are burdening urban transportation networks. The largest cities in the world present a variety of difficulties for those who live and work there. They must deal with growing traffic, longer travel times, and delays. In addition, expenses, annoyance, mishaps, and even fatalities are increasing (Goetz, 2019). Gomes Correia, Winter, and Puppala (2016) state that the market is evolving as more sustainable structures are planned, developed, constructed, maintained, and utilized. The growth of sustainable transportation exerts significant demands on material resources. However, significant difficulties are involved in the decision-making process regarding transportation planning and policies (Illahi & Mir, 2021).

Moving towards a more sustainable future seems to be difficult, according to Narayanaswami (2017), especially considering the variety of interest groups involved, the complexity of urban systems, and the fragmented nature of decision-making in most metropolitan districts. Furthermore, Maity, Roy, and Verdegay (2020) noted that a significant factor in these decisions is not only their complex structure but also the broad participation of stakeholders. Pujiati et al. (2020) state that the provision of mass transit—such as buses, taxis, rickshaws, etc. – along with infrastructure and facilities – such as sidewalks, streetlights, shelters, and roads – allows for implementing sustainable mobility. Johannesburg provides public transportation such as buses (Rea Vaya), South Africa's first BRT, Metrobus, taxis and Gautrain. However, the number of private vehicles is increasing yearly; it causes congestion, hinders economic activity, and causes pollution.

Johannesburg experiences congestion due to the rise in private automobiles not keeping up with the expansion of roads. In the past, public transportation was primarily found in the heart of cities, where dense populations and jobs allowed for many routes, heavy traffic, and frequent connections (Adewumi and Allopi, 2013). According to a study by Ogra and Kgatjepe (2016), middle-class individuals believe public transit is risky, which is one of the reasons they don't utilize it. On the other hand, the urban poor, who cannot afford private vehicles, have no other option and are therefore in a different situation. Furthermore, according to Joseph et al. (2021), the use of informal public transport (IPT)-unscheduled, low-capacity modes of transportation that run without supportive transport facilities linked to several mobility issues for users in the Global South, including poor service, lengthy travel times, and a lack of safety and security. Unsafe conditions in BRT use included overcrowding (which limits ventilation and causes fainting), sexual harassment of women, pushing and shoving during boarding, and hazardous alighting (where the driver did not care or wait for the passengers to alight securely).

Although in distinct ways, both systems (IPT and BRT) were found to have detrimental effects on security and safety during both periods. IPT modes were judged risky, and women thought motorcycles were the riskiest, especially when they were carrying kids (Yanar, 2023). Integrating sustainable transportation technologies is becoming increasingly important as the globe struggles with environmental issues and the need to create more sustainable metropolitan areas. However, several challenges make it more difficult for sustainable ideas to be accepted and implemented. This literature review explores the following challenges:

2.2.1. Lack of adherence to policy and regulatory framework

Public investments in transportation infrastructure can provide positive externalities, such as the knowledge and technology spillover effects, which can directly and indirectly stimulate the economy (Zhang & Hanaoka, 2021). While this is happening, transportation infrastructure development frequently contributes to urban noise and environmental pollution, intensifying the negative consequences. Due to their essential responsibilities and complicated characteristics, transportation infrastructures have a variety of repercussions on the environment, economy, and society (Wang et al., 2018). Furthermore, although the majority of research has focused on the unidirectional long-run causal relationship between growth and transportation infrastructure, Cigu et al. (2018) noted that policy modifications, institutional configurations, and incentives driven by political considerations can all negatively affect the state of transportation infrastructure development and the trajectory of sustainable growth. Furthermore, it occasionally discusses covert strategies that underlie some incorrect political decisions and negatively impact the community and sustainable development.

Inconsistent or antiquated laws and regulations significantly hamper the adoption of sustainable transportation. Governments have a vital role in defining the transportation industry through policy initiatives. Conversely, progress is sometimes hampered by the slow pace of policy updates, disjointed governance structures, and conflicting objectives (Ibarra-Rojas et al., 2015). Authorities must develop clear targets and implementation deadlines for transportation policies while integrating them with sustainability goals to address this issue (Bibri, Krogstie, and Kärrholm, 2020). Moreover, creating a cohesive regulatory structure that promotes innovation and involvement from the private sector might help promote sustainable transportation methods. There are differences between the laws and policies governing urban mobility and the movements of city inhabitants (Cervero, 2013). Inadequate governance and reform capabilities also impede government initiative and action. However, African governments prioritize larger cities over smaller, rapidly growing metropolitan centers for public transportation, partly because of economies of scale (Sietchiping, Permezel, and Ngomsi, 2012). The poor uptake of government-subsidized transit and the persistently high usage of private automobiles indicate that the government does not offer enough public transit or that the service is insufficient to draw users in (Luke and Heyns, 2020).

2.2.2. Lack of political will to support sustainable transportation

Because it is conventional to create infrastructure to facilitate motorized traffic, the current transportation network is biased toward motorized transportation, and even when road development projects are ongoing, facilities for non-motorized transit are still not considered. According to Sietchiping, Permezel, and Ngomsi (2012), walkers and bicycles are not given the same priority as motorized four-wheelers (such as buses, private vehicles, and public transportation) in land use and transportation planning laws and practices. The transportation industry is averse to change because of its long-standing infrastructure and customs. As a result of this reluctance, it may not be easy to implement more sustainable and effective alternatives. Moreover, Pojani and Stead (2018) suggested this might be the case because politicians believe that cycling and walking are outdated and incompatible with their competitiveness and ambitions for economic advancement. According to Rodrigue (2020), there are two main reasons why non-motorized transportation problems arise: either there is excessive traffic, which hinders the movement of bicycles, pedestrians, and other non-motorized vehicles, or there is a flagrant disregard for pedestrians and micro-mobility in the current infrastructure and amenity design.

Transportation networks are complicated by their nature, with multiple modes, parties involved, and rules to follow. It can be intimidating to navigate this complexity to address inefficiencies. Reducing emissions, promoting public transportation, improving accessibility, and ensuring equitable access to transportation are a few competing objectives. A thorough approach is necessary to arrive at the right combination of solutions that fulfil each goal. Cities can use integrated planning approaches to incorporate shared mobility services, walking, cycling, public transportation, and other sustainable modes of transportation (World Bank Group, 2021). Stakeholder involvement and data-driven decision-making can also help identify trade-offs and synergies between various transportation goals. According to Sietchiping, Permezel, and Ngomsi (2012), one crucial component is that politicians and urban planners acknowledge the range of mobility options and consider them all when creating urban planning and management strategies.

2.2.3. Poor public perception and acceptance of support for sustainable transportation

Public perception and acceptance of sustainable road transport infrastructure can be challenging due to various factors. Here are some of how this challenge manifests:

Individuals used to driving private automobiles may be reluctant to accept sustainable transportation options like cycling or public transportation because they frequently oppose changes in their commuting patterns (Andersson, 2020). Sustainable transportation infrastructure, such as bike lanes and public transportation, might not exist or be poorly connected in some areas. People may be deterred from exploring these options by limited availability. Public opposition to changes in transportation behavior and habits may stem from several factors, such as a lack of understanding, a fear of inconvenience, and doubts about the advantages of sustainable programs (Pettersson, Stjernborg, and Curtis, 2021). In addition, utilizing a personal automobile may be seen as more convenient or time-efficient than sustainable transportation solutions. People may be discouraged from adopting more environmentally friendly options due to this belief (Zeng et al., 2022). Therefore, public opinion and behavior regarding sustainable mobility are the main concerns of transportation planners and policymakers. Adopting sustainable transportation solutions can be accelerated, and a sense of ownership can be developed by including the community in decision-making and early public opinion gathering (Kyriakidis et al., 2023).

Considerations about safety and dependability have an impact on public opinion. Sustainable transportation solutions must be seen as dependable and safe (Al-Turjman et al., 2023). Therefore, safety is the priority for those thinking about using sustainable transportation. People may choose not to bike, walk, or take public transportation out of fear of accidents or criminal activity. First and foremost, it needs to be acknowledged that the suggested policy package is thought to be successful and efficient. People usually first assess a particular behavioral activity by considering its advantages and disadvantages in light of their cognitive beliefs. This process results in the formation of an attitude toward that particular action. Farzaneh et al. (2019) asserted that winning over the public requires clear communication of the advantages of sustainable road transport infrastructure, such as decreased traffic, better air quality, and increased safety. Campaigns for public awareness and the dissemination of information are essential in influencing people's perceptions. Participating in sustainable road infrastructure projects' planning and decision-making stages with the local community can increase acceptance. Concerns, desires, and possible solutions can be identified with the community's assistance. Campaigns for public education, school initiatives, and seminars can increase knowledge of environmentally friendly transportation choices and the significance of minimizing the impact of road travel (Oeschger et al., 2020).

3. Research methodology

The paper adopted a quantitative research method involving both descriptive and exploratory research methods to assess the challenges facing incorporating sustainability into the existing transport infrastructure of Johannesburg. The study area was the city of Johannesburg in the Gauteng province, South Africa. The targeted respondents were the people responsible for the delivery and construction of the road infrastructure. These include the employees at public works and road construction. This study's data collection method was in the form of a survey. The questionnaires were also in the form of closed-ended multiple-choice questions. According to Abdolreza Gharehbagh et al. (2022), closed-ended questions yield a restricted number of responses, which can be coded in a database using a number or symbol to indicate a response. The questionnaire was designed to have two sections where the first section covered the demographic information of the respondents, and the second section covered 5-point Likert-scaled questions on the challenges identified from reviewed literature. The questionnaires were distributed using Google Forms and sent to respondents via the LinkedIn platform and emails between September and October 2023.

The data was analyzed after receiving the responses from the study participants. The goal of data analysis is to discover underlying patterns, trends, and relationships within a study's context (Seyedan & Mafakheri, 2020). The researcher employed IBM SPSS, a statistical software tool, to compile data once the survey participants completed the questionnaires. The researchers then calculated central tendency statistics to assess the data. The analysis and interpretation of the results were based on a four-part survey, which formed the basis for collecting quantitative data. All the questions in the survey received responses. Initially, 150 survey questionnaires were distributed exclusively through Google Forms, and ultimately, 91 individuals responded, accounting for a response rate of 61% among the total recipients.

The respondents' responses were analyzed using the Mean Item Score (MIS), which ranked the variables according to importance. Factor analysis was also used to investigate if the variables are linearly related to other variables. According to Shrestha (2021), factor analysis is concerned with whether the covariance or correlation between a set of observed variables can be explained in terms of a smaller number of unobserved constructs known as either latent variables or common factors. The Cronbach's alpha (α) reliability test was carried out because of the importance of reliability in test results and the requirement to sustain the validity of research findings. Cronbach's alpha was used to test internal consistency and establish the instrument's reliability. Nawi et al. (2020) state that a Cronbach's alpha score of greater than 0.6, or acceptable between 0.6 and 0.8, indicates that an item is dependable. The scale and instrument utilized are accurate for measuring the challenges of incorporating sustainability into the existing transport infrastructure, as shown by the value of 0.894.

4. Findings and discussions

4.1. Challenges of incorporating sustainability into transportation infrastructure

The findings revealed in Table 1 show that "Lack of political commitment to support sustainable transportation", garnered the top position with an average score of 4.02 and a standard deviation of 1.00. Following closely in second place was the issue of the "Insufficient investment in vehicles with reduced energy consumption", scoring an average of 3.96 and a standard deviation of 0.906. In third place, respondents highlighted "Resource constraints for achieving sustainable infrastructure", yielding an average score of 3.84 with a standard deviation of 1.067. Additionally, the survey results underscored the industry's heavy reliance on a single fossil fuel source, petroleum, which occupied the fourth position with an average score of 3.79 and a standard deviation of 1.101. Furthermore, "Concerns regarding the reliability of public transportation" secured the fifth spot with an average score of 3.78 and a standard deviation of 1.073. The survey indicated that "Generous parking and road capacity standards" were the lowest, with an average score of 3.23 and a standard deviation of 0.932.

Table 1: Descriptive statistics of challenges of incorporating sustainability into the transportation infrastructure

Challenges	Mean	Std. Deviation	Ranking
Lack of political will to support sustainable transportation	4.02	1.000	1
Lack of investment in less energy consumption vehicles	3.96	0.906	2
Resource limitations to make current infrastructure sustainable	3.84	1.067	3
The transportation industry relies heavily on a sole fossil fuel source, which is petroleum	3.79	1.101	4
Concerns over the reliability of public transport	3.78	1.073	5
Concerns over the safety of public transport	3.76	1.109	6
Lack of urban transport governance systems	3.76	0.923	6
Lack of adherence to policy and regulatory framework	3.68	0.893	8
High cost of building infrastructures	3.62	1.113	9
Lack of public support for sustainable transportation.	3.62	1.103	9
Excessive transport land consumption	3.51	0.911	11
Zoning laws and development practices that favour automobile-oriented land use	3.43	0.956	12
Generous parking and road capacity standards	3.23	0.932	13

4.2. Factor analysis for the challenges of incorporating sustainability into transportation infrastructure

Factor analysis was carried out to establish the variables that could measure aspects of the exact underlying dimensions. The suitability of the data was accessed before the principal component analysis was carried out. To examine if the distribution of the data was adequate for factor analysis, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was employed. As opined by Field (2009), a data set that attained a KMO index of 0.50 and a Bartlett's test of sphericity where ($p< 0.05$) is good enough for factor analysis. Table 2 indicates that the value of the KMO index is equal to 0.860 (greater than 0.5), and Bartlett's test of sphericity is significant ($p = 0.000$). These results indicate that the sampling is adequate for factor analysis.

Table 2: KMO and Bartlett's test for the challenges of incorporating sustainability into transportation infrastructure

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.860
Bartlett's Test of Sphericity	Approx. Chi-Square	673.369
	df	78
	Sig.	0.000

4.2.1. Challenges of incorporating sustainability into transportation infrastructure

Table 3 reveals that 3 components with eigenvalues greater than 1.0 were extracted using the factor loading of 0.30 as the cut-off point which was recommended by Pallant (2005). The total variance explained by each component extracted is as follows: component 1 (46.52%), component 2 (9.45%), and component 3 (8.89%). Therefore, the final statistics of the principal component analysis and the components extracted accounted for approximately 65% of the total cumulative variance among the factors since it is rare to divide behavior into different groups that function independently and neatly. Thus, using an orthogonal rotation will lead to a loss of valuable information if a correlation exists among the factors. Theoretically, oblique rotation should render a more accurate solution. Oblimin rotation, which is an oblique rotation method, was preferred to varimax, an orthogonal rotation method, because, in the social sciences, some form of correlation is generally expected to exist among the factors since it is very rare to neatly divide behavior into different groups that function independently of each other. If no correlation exists among the factors, oblique and orthogonal rotation produce almost identical results (Zhang et al., 2023).

Table 3: Total Variance Explained for Challenges of incorporating sustainability into transportation infrastructure

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[a]
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	Total
1	6.048	46.520	46.520	6.048	46.520	46.520	5.068
2	1.228	9.449	55.969	1.228	9.449	55.969	3.401
3	1.156	8.890	64.859	1.156	8.890	64.859	3.960
4	0.896	6.891	71.750				
5	0.835	6.422	78.172				
6	0.569	4.380	82.552				
7	0.479	3.685	86.238				
8	0.404	3.105	89.342				
9	0.393	3.025	92.367				
10	0.348	2.674	95.041				
11	0.295	2.269	97.310				
12	0.215	1.656	98.966				
13	0.134	1.034	100.000				

Extraction Method: Principal Component Analysis.
a. When components are correlated, sums of squared loadings cannot be added to obtain a total variance.

The pattern matrix shown in Table 4 expresses the coefficients for the linear combination of measured variables. Negative factor loadings indicated that the variables will be interpreted differently. However, this does not exclude them from the constructs. Each factor was named by using a name that reflects all the variables. The three-factor groupings are reported as follows.

i. A total of seven (7) variables loaded onto factor 1 as shown in Table 4 indicates that these variables are identified as the topmost factors for the prevalent stress causes. These factor loads 'High cost of building infrastructures', 'Lack of investment in less energy consumption vehicles', 'The transportation industry relies heavily on a sole fossil fuel source, which is petroleum', 'Excessive transport land consumption', 'Resource limitations to make current infrastructure sustainable', 'Lack of urban transport governance systems' and 'Generous parking and road capacity standards'. The cluster was named **"Sustainability and Resource Management Challenges"** and accounts for 46.520 percent of the variance.

ii. A total of two (2) variables were loaded onto Factor 2 as shown in Table 4. This factor loads 'Concerns over the safety of public transport' and 'Concerns over reliability of public transport'. They were collectively named **"Trust and Reliability Challenges, " accounting** for 9.449 percent of the variance.

iii. Four (4) variables were loaded onto Factor 3 as shown in Table 4. This factor loads ' lack of political will to support for sustainable transportation', 'Lack of adherence to policy and regulatory framework', 'Zoning laws and development practices that favor automobile-oriented land use', and 'Lack of public support for sustainable transportation'. Therefore, they were collectively called **"Policy and Public Engagement Challenges, " accounting** for 8.890 percent of the variance.

Table 4: Pattern matrix for the challenges of incorporating sustainability into the transportation infrastructure

	Component		
	1	2	3
High cost of building infrastructures	0.908		
Lack of investment in less energy consumption vehicles	0.778		
The transportation industry relies heavily on a sole fossil fuel source, which is petroleum	0.756		
Excessive transport land consumption	0.656		
Resource limitations to make current infrastructure sustainable	0.642		
Lack of urban transport governance systems	0.475		
Generous parking and road capacity standards	0.424		
Concerns over the safety of public transport		-0.927	
Concerns over the reliability of public transport		-0.921	
Lack of political will to support sustainable transportation.			0.879
Lack of adherence to policy and regulatory framework			0.769
Zoning laws and development practices that favour automobile-oriented land use			0.594
Lack of public support for sustainable transportation.			0.594

4.3. Discussion

The study's findings highlight a prevailing sentiment among respondents that the transportation industry lacks the political will to prioritize sustainability. As noted by Remme et al. (2022), entrenched infrastructure and well-established procedures in the sector create resistance to change and hinder the implementation of more sustainable alternatives. Politicians' perception of walking and cycling as regressive, in conflict with economic advancement objectives, further contributes to this reluctance (Pojani and Stead, 2018). Additionally, the mismatch between urban mobility laws and current behaviors, coupled with a lack of governance and reform competence, poses obstacles to effective government plans and actions. The preference for larger cities in public transportation investments by African governments may neglect the needs of smaller, rapidly growing metropolitan regions, leading to poor uptake of government-subsidized transit and continued reliance on private motor cars (Luke and Heyns, 2020).

Another significant impediment to sustainable mobility is the insufficient investment in energy-efficient vehicles. Despite the global focus on climate change and carbon emissions reduction, recent research (Hung et al., 2021) reveals that most funding in the automotive sector still goes to traditional, fuel-inefficient cars. Factors such as established infrastructure for conventional vehicles, resistance to new technology, and prioritization of short-term financial concerns over long-term environmental benefits contribute to this investment disparity (Mastoi et al., 2022). Without substantial investment in energy-efficient vehicles, the transition to a sustainable transportation system faces challenges, hindering progress toward environmental goals (Chukwuemeka et al., 2023). Additionally, the lack of financial resources poses a hurdle to implementing sustainable transportation infrastructure, making adopting eco-friendly solutions like bike lanes and electric buses financially tricky. The need for collaboration between the public and private sectors in complex financing schemes further complicates the funding landscape for sustainable transportation projects (Shah et al., 2021).

From the Factor analysis carried out on the Challenges of incorporating sustainability into transportation infrastructure, three factors emerged and are discussed as follows,

Cluster Factor 1 – Sustainability and resource management challenges

A total of seven (7) variables were loaded onto factor one; these variables are the High cost of building infrastructures (0.778), 'Lack of investment in less energy consumption vehicles', 'The transportation industry relies heavily on a sole fossil fuel source, which is petroleum (0.756), 'Excessive transport land consumption (0.656), 'Resource limitations to make current infrastructure sustainable (0.642), 'Lack of urban transport governance systems (0.475)' and 'Generous parking and road capacity standards (0.424). These loaded variables in this factor are the most essential challenges of incorporating sustainability into transportation infrastructure.

Incorporating sustainability into transportation infrastructure presents several essential challenges, including the high cost of building infrastructures and the lack of investment in less energy-consuming vehicles. Hjort et al. (2022) stated that the high cost of building infrastructures is a significant obstacle to sustainable transportation, as it requires substantial investment in constructing and maintaining transportation systems under climate change conditions. Kurniawan et al. (2020) also stated that the lack of investment in less energy-consuming vehicles hinders the transition to sustainable transportation, leading to continued reliance on traditional vehicles with high energy consumption rates. Stanković et al. (2021) also stated that the heavy reliance on petroleum as the primary fossil fuel source for transportation poses a significant obstacle to achieving sustainability. The complexity of achieving sustainability in public transportation is influenced by various factors, including the surrounding urban form and governance structures (Karjalainen & Juhola, 2019).

Cluster Factor 2 – Trust and Reliability Challenges

The extracted variables loaded onto factor two are 'Concerns over public transport safety (-0.927) and 'Concerns over reliability of public transport (-0.921)'. These factors are essential Challenges of incorporating sustainability into the transportation infrastructure. These challenges are crucial to address to promote sustainable urban mobility. One key challenge is ensuring that public transport is safe and reliable, which requires solid public policies to steer digitalization towards fostering sustainability in urban transport (Creutzig et al., 2019). Additionally, Biehle (2022) stated that the social dimension of sustainable urban transportation, including indicators such as affordability, inclusivity, accessibility, and satisfaction with public transport, needs to be considered to address concerns over safety and reliability. Furthermore, Jordová and Foltýnová (2021) stated that broad and active public support and proper communication between transport experts and the public are essential for the successful implementation of sustainable mobility in cities.

Cluster Factor 3 - Policy and Public Engagement Challenges

The four (4) extracted variables loaded onto factor three are ''Lack of political will to support for sustainable transportation (0.879), Lack of adherence to policy and regulatory framework (0.769), Zoning laws and development practices that favor automobile-oriented land use (0.594) and lack of public support for sustainable transportation (0.594). These factors are essential challenges of incorporating sustainability into transportation infrastructure. Incorporating sustainability into transportation infrastructure is a multifaceted challenge that involves economic, environmental, and social aspects. One of the essential challenges in this endeavor is the lack of political will to support sustainable transportation. According to Ge et al. (2020), this is evident in the need to strengthen collaboration among multiple interest groups, boost the national mood, and diversify the identity of policy entrepreneurs to set the policy agenda for sustainable intermodal transport.

Moreover, Syahbandi et al. (2022) added that individual modal choice decision-making plays a key role in designing a sustainable transportation strategy, emphasizing the importance of considering individual preferences and behaviors in policy development. According to Karjalainen and Juhola, (2019), Zoning laws and development practices prioritizing automobile-oriented land use have been identified as a significant obstacle to sustainable transportation. Furthermore, the lack of public support for sustainable transportation is a critical challenge that needs to be addressed. The shift towards sustainable transportation requires public acceptance and participation (Yanar, 2023). Without public support, initiatives to promote public transportation, cycling, and walking may face resistance and limited uptake, impeding the transition to a more sustainable transportation system (Salisu et al., 2023).

5. Conclusions and recommendations

This study has identified and analyzed key challenges in incorporating sustainability into Johannesburg's transport infrastructure. The findings highlight several critical issues:

1. Lack of political commitment to support sustainable transportation emerged as the most significant challenge, underscoring the need for stronger policy frameworks and governmental support.
2. Insufficient investment in energy-efficient vehicles and resource constraints for achieving sustainable infrastructure were identified as major obstacles, pointing to the need for increased financial allocation and strategic resource management.

3. The heavy reliance on petroleum as a single fossil fuel source was highlighted, emphasizing the urgency of diversifying energy sources in the transport sector.
4. Public perception issues, including concerns about the reliability of public transportation, were identified as significant barriers to adoption of sustainable transport options.

These findings highlight the complex nature of integrating sustainability into Johannesburg's transport infrastructure, encompassing environmental, economic, and social dimensions.Implications: The study underscores the urgent need for a comprehensive approach to sustainable transport development in Johannesburg. This includes modernizing and expanding existing infrastructure to accommodate population growth and economic activities while addressing issues such as traffic congestion, air pollution, and inadequate public transportation options.The research emphasizes the importance of improved coordination among stakeholders, including government bodies, private sector entities, and the community. This coordination is crucial for aligning efforts and resources to support sustainable transport infrastructure development.

Limitations:

This study focused solely on Johannesburg, which may limit the generalizability of findings to other urban contexts. Additionally, the research relied on quantitative data, which may not capture the full complexity of the challenges faced.

Recommendations:

1. Policy Development: Develop and implement comprehensive policies that prioritize sustainable transportation initiatives.
2. Investment Strategies: Increase investment in energy-efficient vehicles and sustainable infrastructure.
3. Diversification of Energy Sources: Reduce reliance on petroleum by exploring and implementing alternative fuel sources for transportation.
4. Stakeholder Engagement: Establish platforms for improved coordination and collaboration among various stakeholders.
5. Public Awareness: Implement campaigns to educate the public about the benefits of sustainable transportation and address concerns about reliability and safety.

Future Research:

Further studies should explore specific strategies for overcoming the identified challenges, potentially including case studies of successful sustainable transport initiatives in similar urban contexts. Additionally, research into innovative financing mechanisms for sustainable transport infrastructure could provide valuable insights for policy-makers and urban planners.

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Conflicts of Interest

The authors declare no conflict of interest.

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