From Gridlock to Green Flow: Electric Buses and the Reconfiguration of Urban Mobility in South Africa

Olawale Akinrinde, PhD
Postdoc, University of the Free State, South Africa
Senior Lecturer, Department of Political Science, Osun State University, Nigeria
olawale.akinrinde@uniosun.edu.ng
https://orcid.org/0000-0001-7350-2376

Abstract

Urban mobility in Sub-Saharan Africa is increasingly defined by a tension between rapid urbanisation and fragile, overstretched public transportation systems. In Johannesburg, these pressures manifest in persistent congestion, unreliable services, overcrowding, and deepening spatial inequalities. The study investigates how electric buses, positioned as a practical expression of Fourth Industrial Revolution (4IR) mobility innovations, can contribute to the reconfiguration of urban transport within a selected South African university context. Moving beyond broad and often abstract invocations of 4IR technologies, the study centres specifically on electric bus systems as a grounded, scalable intervention capable of transforming mobility outcomes. Drawing on qualitative data from in-depth interviews with 15 purposively selected participants, along with archival and documentary evidence, the research examines both the operational effectiveness and the lived experiences associated with the introduction of electric buses into the institution's transport system. Anchored in the Diffusion of Innovations theory, the study analyses how this technological intervention is adopted, perceived, and integrated within an existing mobility ecosystem. It explores the extent to which electric buses enhance efficiency, reduce congestion, improve accessibility, and contribute to environmentally sustainable transport practices. At the same time, the study critically interrogates the socio-technical barriers to adoption, including cost constraints, user perceptions, infrastructural limitations, and institutional readiness. The findings reveal that while electric buses hold significant promise in transitioning urban mobility systems from gridlock to green flow, their transformative potential depends on supportive policy frameworks, user acceptance, and integrated transport planning.

Keywords: Urban Mobility, Electric Buses, Sustainable Transport, Fourth Industrial Revolution, Diffusion of Innovations, Johannesburg, Just Urban Transition

Introduction

Urban mobility in Sub-Saharan Africa is increasingly defined by a tension between rapid urbanisation and fragile, overstretched transportation systems. In Johannesburg, a city widely considered South Africa's economic hub, this tension has been most visible in the persistent gridlock that characterises everyday mobility, marked by congestion, unreliable services, overcrowding, and deepening spatial inequalities (Gullino & Rubin, 2026). These challenges not only undermine the efficiency of public transportation but also limit access to economic opportunities and social services, particularly for populations located in peripheral urban areas. The urgent question, therefore, is how cities such as Johannesburg can transition from a state of systemic gridlock to a more sustainable, efficient, green flow of urban mobility.

Globally, cities are increasingly turning to Fourth Industrial Revolution (4IR) technologies to address similar mobility challenges (Cervero, 2017). For example, Singapore's implementation of AI-driven traffic management systems has reduced congestion and improved travel times by dynamically adjusting traffic signals based on real-time data (Gawer, 2022).

Similarly, in Europe, the adoption of autonomous electric buses in urban centres has enhanced the efficiency and sustainability of public transport networks. These global examples underscore the transformative potential of 4IR-driven mobility innovations and highlight the importance of adapting such solutions to local contexts. However, the adoption of these technologies in African cities, including Johannesburg, remains limited due to structural, financial, and policy constraints.

No doubt, the current public transportation landscape in Johannesburg is marred by significant inefficiencies. Public transport options, such as buses, minibus taxis, and trains, often suffer from frequent delays, safety concerns, overcrowding, and poor maintenance (IOL, November 4, 2022). The city's reliance on traditional transportation modes, combined with rapid urban growth, has exacerbated traffic congestion and environmental pollution, significantly impeding residents' mobility (IOL, November 4, 2022). Moreover, the lack of integration among different transport modes has resulted in a fragmented and unreliable system that fails to meet the diverse needs of the urban population.

These challenges are not merely technical or operational; they are deeply embedded in broader socio-economic and spatial inequalities with serious implications for the ideals of a just urban transition. A significant proportion of Johannesburg's population resides in peripheral areas with limited access to efficient and affordable transportation, thereby reinforcing patterns of exclusion

and uneven development. The inability of the existing public transport system to respond to these evolving urban dynamics underscores the urgent need for innovative, sustainable, and inclusive mobility solutions.

In this context, the Fourth Industrial Revolution (4IR) becomes particularly relevant. The 4IR refers to the convergence of digital, physical, and intelligent technologies that enable real-time communication, automation, and data-driven decision-making (Schwab, 2016). In the domain of urban transportation, this includes innovations such as artificial intelligence (AI), the Internet of Things (IoT), big data analytics, smart sensors, autonomous vehicles, and electric mobility systems (Priyono, Akinrinde, Al Fithri & Azhar, 2026). These technologies offer significant potential to transform public transportation by improving efficiency, enhancing user experience, and promoting environmental sustainability (Schalekam & Behrens, 2020; Schwab, 2016).

However, while existing discourses on 4IR technologies have often remained broad and abstract, there is a need to ground these innovations in specific, practical interventions that can be empirically examined (Akinrinde, 2025). In this study, electric buses are conceptualised as a concrete manifestation of 4IR-enabled mobility transformation, representing a shift towards cleaner, smarter, and more sustainable public transportation systems. Electric buses not only reduce carbon emissions but also integrate with data-driven systems for route optimisation, energy efficiency, and service delivery, thereby embodying the transition from conventional transport models to intelligent mobility ecosystems.

The selected institution, a leading higher education institution in Johannesburg, provides a compelling microcosm for examining this transition. The institution has proactively embraced technological innovation within its transport system, particularly through the introduction of electric buses and data-driven mobility solutions. These initiatives reflect a deliberate effort to move towards a more sustainable and efficient transport model, aligning with broader global trends in green mobility. As such, the institution offers a unique setting to explore how electric bus systems can help reconfigure urban mobility in a controlled yet representative environment.

The institution’s model also offers an opportunity to examine how such innovations are experienced, adopted, and integrated into an existing transport ecosystem. Its deployment of electric-powered buses, alongside smart sensors and data analytics for transport management, represents a significant step towards modernising mobility systems. At the same time, it raises

important questions about user acceptance, infrastructural readiness, cost implications, and the broader scalability of such interventions within the wider Johannesburg context.

Despite these promising developments, there remains limited empirical evidence on the effectiveness of such technologies in real-world settings, particularly within African cities. Challenges related to high implementation costs, resistance to change, and regulatory limitations continue to hinder the widespread adoption of innovative mobility solutions. Consequently, there is a critical need to understand not only the technical potential of these interventions but also the social, institutional, and policy dynamics that shape their success or failure.

The central problem this study seeks to explicate is therefore the lack of clear, context-specific evidence on how 4IR-enabled mobility interventions, particularly electric buses, can be effectively harnessed to improve efficiency, accessibility, and sustainability within existing public transportation systems in Johannesburg. By focusing on a university-based transport system as a microcosm, this study seeks to bridge this gap.

Drawing on Everett Rogers's (2003) Diffusion of Innovations theory, it examines how electric bus systems are introduced, perceived, and adopted within the selected institution, and how these processes influence their effectiveness. Specifically, the study further evaluates the extent to which electric buses have contributed to reducing congestion, improving mobility, and promoting sustainable urban development. It also seeks to identify the opportunities and constraints associated with their implementation, as well as the broader implications for scaling such innovations across the city.

Ultimately, this study also contributes to ongoing debates on sustainable urban mobility by demonstrating how targeted, context-sensitive innovations can facilitate the transition from urban gridlock to green flow. The study provides empirical and policy-relevant insights into how African cities can leverage emerging technologies to build more inclusive, efficient, and environmentally sustainable transportation systems while entrenching the ideals of a just urban transition.

Literature Review: Debates, Context, and Conceptual Framing

Debating the Fourth Industrial Revolution and Urban Mobility

The growing body of extant studies on the Fourth Industrial Revolution (4IR) presents it as a transformative force reshaping economic systems, governance structures, and urban life. At its core, the 4IR involves integrating advanced technologies, such as artificial intelligence (AI), the Internet of Things (IoT), big data analytics, and autonomous systems, into everyday processes,

including urban transportation (Schwab, 2016). Within mobility studies, a dominant strand of scholarship adopts a techno-optimistic perspective, arguing that innovations can significantly enhance transport efficiency, reduce congestion, and improve the user experience (Gawer, 2022; Cohen & Hopkins, 2019). From this viewpoint, intelligent transport systems, predictive analytics, and automation are therefore seen as critical tools for addressing the growing pressures of urbanisation driven by population growth.

However, this optimism is increasingly contested by a more critical body of literature that questions the uneven distribution of technological benefits and the socio-political implications of 4IR adoption. Scholars have argued that while technologies promise efficiency, they may also reproduce or even deepen existing inequalities, particularly in contexts where infrastructure, governance, and institutional capacity are weak, as in most developing societies (Pojani & Stead, 2018). This debate highlights a central tension within the 4IR discourse: whether technological innovation alone can resolve deeply embedded structural challenges in urban systems.

4IR and Mobility in the African Context

This tension becomes even more pronounced when situated within African cities. While global studies often highlight the successes of 4IR-driven mobility systems in developed regions, their applicability to African contexts remains uncertain. Cities such as Johannesburg are characterised by rapid urbanisation, infrastructural deficits, fragmented transport systems, and pronounced socio-economic inequalities. Existing studies on urban mobility in Johannesburg largely focus on these structural challenges, such as congestion, spatial inequality, and limited accessibility, without sufficiently engaging with the potential of emerging technologies to address them (Venter, Mahendra, and Hidalgo, 2019).

Moreover, much of the literature on 4IR technologies in mobility remains externally oriented, drawing heavily on experiences from Europe and Asia. For instance, studies by Cohen and Hopkins (2019) emphasise the operational benefits of autonomous vehicles, while Gawer (2022) highlights the efficiency gains of AI-driven traffic systems. However, these analyses often overlook the contextual realities of African cities, including financial constraints, governance limitations, and the persistence of informal transport systems. As a result, there is growing recognition that the 4IR cannot be understood as a universal or one-size-fits-all solution but must be interpreted through context-sensitive, place-based frameworks.

From Abstract Technologies to Grounded Interventions: Electric Buses as a Game-Changer

A key limitation in the existing literature is its tendency to treat 4IR technologies in broad and abstract terms. While concepts such as AI, automation, and smart systems dominate scholarly discussions, comparatively little attention is paid to specific, implementable interventions that can be empirically evaluated in real-world contexts. This study addresses this gap by focusing on electric buses as a concrete and scalable manifestation of 4IR-enabled mobility transformation.

Unlike more capital-intensive or speculative technologies such as fully autonomous vehicles, electric buses represent a practical convergence of digital, environmental, and infrastructural innovation. They embody elements of the 4IR through their integration with data-driven systems for route optimisation, energy management, and operational efficiency, while advancing sustainability goals by reducing carbon emissions. In this sense, electric buses serve as a bridge between the abstract promises of the 4IR and the material realities of urban transport systems.

Barriers to Adoption: Infrastructure, Governance, and Social Acceptance

Despite their potential, the adoption of 4IR-enabled mobility solutions in African cities faces significant structural and institutional barriers. Financial constraints remain a major challenge, as the high cost of implementing advanced technologies limits their accessibility for public transport systems operating within constrained budgets (Venter, Mahendra, and Hidalgo, 2019). In addition, resistance from key stakeholders, including traditional transport operators and commuters, complicates the transition to new mobility systems.

Regulatory and governance challenges further constrain adoption. Existing policy frameworks are often ill-equipped to accommodate emerging technologies, creating uncertainty around issues such as data governance, cybersecurity, and ethical accountability (Pojani & Stead, 2018). These challenges underscore the importance of not only technological innovation but also institutional readiness and policy alignment in enabling successful mobility transitions.

Sustainability, Inclusion, and the Just Urban Transition

The integration of 4IR technologies into public transportation systems is closely linked to broader debates on sustainable urban development. The United Nations Sustainable Development Goals (SDGs), particularly SDG 11, emphasise the need for inclusive, safe, resilient, and sustainable cities (United Nations, 2015). In this regard, mobility is not merely a technical issue but a question of social justice, accessibility, and environmental responsibility.

While existing studies acknowledge the environmental benefits of green mobility solutions, there is limited empirical work examining how such innovations contribute to a just urban transition in African cities. The risk remains that technologically advanced systems may benefit certain groups while excluding others, particularly in contexts marked by inequality and uneven access to infrastructure.

Conceptual Framing and Research Gap

This study adopts a Diffusion of Innovations perspective to examine how electric bus systems are introduced, adopted, and integrated within an existing transport ecosystem. This framework is particularly useful in understanding not only the technical performance of innovations but also the social processes that shape their acceptance and impact. It situates the university-based transport system as a microcosm. It provides a context-specific, empirically grounded analysis of how electric buses can facilitate the transition from urban gridlock to green flow without deepening the socioeconomic and structural inequalities embedded in the city. In doing so, the study addresses a critical gap in the literature: the lack of empirical studies that move beyond abstract discussions of 4IR technologies to examine their practical application, limitations, and transformative potential within African just urban contexts.

Theoretical Framework: Reframing Diffusion in Socio-Technical Transitions

This study hinges on Diffusion of Innovations, which provides a foundational lens for understanding how new technologies are adopted, contested, and normalised within social systems. While Rogers' classical formulation conceptualises diffusion as a linear process through which innovations spread over time via identifiable adopter categories, innovators, early adopters, early majority, late majority, and laggards, it extends and problematises this framework by situating it within the complexities of urban mobility transitions in the Global South (Rogers, 2003).

At its core, Diffusion of Innovations posits that the uptake of any innovation is shaped by five key attributes: relative advantage, compatibility, complexity, trialability, and observability. In the context of electric buses as a 4IR-enabled intervention, these attributes take on layered meanings. For instance, the relative advantage of electric buses is not merely economic or environmental but is also embedded in questions of energy justice, infrastructural reliability, and long-term sustainability. Similarly, compatibility must be understood not only in technological terms but also

in relation to entrenched informal transport systems, commuter habits, and the political economy of mobility in Johannesburg.

However, applying DoI in African urban contexts requires moving beyond its traditional pro-innovation bias. As critics have argued, the theory often assumes that innovations are inherently beneficial and that resistance is a problem to be overcome rather than a signal of deeper structural contradictions. This study, therefore, adopts a critical diffusion perspective, recognising that non-adoption or delayed adoption may reflect rational responses to systemic inequalities, infrastructural deficits, or governance failures. In this sense, diffusion is not simply a matter of communication and time but is deeply entangled with power, access, and institutional capacity.

Furthermore, this study reconceptualises diffusion as a socio-technical process, drawing implicitly on insights from transition studies and urban political economy. Electric buses are not standalone technologies; they are embedded within broader systems of energy provision, regulatory frameworks, urban planning, and everyday mobility practices. Their diffusion is therefore contingent on the alignment or misalignment of multiple systems, including state policy, private-sector interests, and user acceptance. This shifts the analytical focus from individual adoption decisions to systemic conditions of possibility.

In the selected university context, the introduction of electric buses represents a micro-level experimentation space, a living laboratory, through which broader diffusion dynamics can be observed. Universities, as semi-autonomous institutional environments, often act as early adopters of innovation due to their relative resource stability and openness to experimentation. However, translating such innovations from enclave spaces into the wider urban fabric is neither automatic nor guaranteed. How and whether innovations can succeed in controlled institutional settings and be diffused into complex, unequal urban systems like Johannesburg underscores the raison d'etat of this study.

Importantly, the framework also foregrounds the role of communication channels and social networks in shaping perceptions of electric mobility. In contexts where trust in public institutions may be uneven, peer networks, user experiences, and informal narratives play a crucial role in mediating acceptance. Thus, diffusion is not merely a technical rollout but a process of meaning-making, where technologies are interpreted, negotiated, and sometimes resisted.

By integrating these critical and contextual insights, this study advances Diffusion of Innovations from a descriptive model to an analytical tool for interrogating the politics of technological

transition. It allows for a nuanced understanding of how electric buses, as embodiments of the Fourth Industrial Revolution, are not simply adopted but actively shaped and, in turn, reshape the socio-economic and infrastructural realities of urban Africa.

Ultimately, this framework enables the study to move beyond the question of *whether* electric buses work to the more complex and policy-relevant question of under what conditions, for whom, and with what implications they contribute to a just and sustainable reconfiguration of urban mobility.

Research Methods

This study adopted a qualitative research design to examine how Fourth Industrial Revolution (4IR) technologies, specifically electric buses, were integrated, experienced, and interpreted within the selected institution's transportation system. Rather than treating technological adoption as a purely technical outcome, the study approached it as a socially embedded process, shaped by user perceptions, institutional strategies, and broader infrastructural and governance realities.

Primary data were generated through in-depth semi-structured interviews with 15 purposively selected participants. These included end users of the institution's electric bus system (students and staff, mostly postdoctoral research fellows who use the electric buses) and taxi drivers from the Central Business District (CBD) Taxi Rank in Johannesburg. This combination enabled the study to capture both lived experiences and institutional perspectives on the innovation.

The interviews explored participants' perceptions of the electric bus system, focusing on its perceived benefits, usability, reliability, and broader mobility implications. Particular attention was paid to how different participant groups interpreted and responded to system features, including data-driven scheduling, smart monitoring technologies, and the transition from conventional to electric mobility. To complement these perspectives, the study further drew on a robust body of archival and documentary evidence, purposively selected to reflect the institutional vision and implementation strategies behind the innovation. These included core university policy and strategy documents such as the *Energy, Resource, Waste and Sustainability (ERWSus) Plan* (2022), the *UJ Sustainability Reports* (GRI-G4 framework), the *Sustainable Development Goals (SDG) impact reports* (2023a; 2023b), and the *Strategic Plan 2025–2035*. These documents provided insight into how electric mobility was framed within broader institutional commitments to sustainability, carbon reduction, and green transitions.

In addition, the study incorporated external documentary sources, including institutional news outputs and independent media coverage. Reports from platforms such as *Engineering News*, *ITWeb*, *IOL*, and *BusinessTech Africa*, alongside official university news releases, were analysed to capture how the innovation was represented, operationalised, and contested beyond formal policy narratives. This enabled the study to engage with both internal institutional framing and external public discourse.

All data, interviews, institutional documents, and media sources were analysed using thematic analysis, guided by Virginia Braun and Victoria Clarke's (2006) six-phase framework. This involved systematic familiarisation with the data, initial coding, theme development, review, refinement, and synthesis into coherent analytical narratives.

The analysis was further structured using Diffusion of Innovations as a guiding analytical lens. The five key attributes of innovation, relative advantage, compatibility, complexity, trialability, and observability, were used to interrogate how electric buses were perceived and adopted within the institutional context. At the same time, the analysis remained open to emergent themes, including infrastructural constraints, governance dynamics, and issues of trust and accessibility, which extended beyond the original model.

This triangulated approach strengthened the validity of the findings. It enabled a more nuanced understanding of how electric mobility innovations were simultaneously designed, governed, experienced, and interpreted across different actor groups.

Presentation of Findings

The findings presented in this study emerged from thematic analysis of qualitative interview responses generated through purposive engagement with users of the selected institution's electric bus system. The analysis focused on participants' lived experiences, perceptions of electric mobility technologies, awareness of Fourth Industrial Revolution (4IR) transport innovations, and the broader implications of these technologies for sustainable urban mobility and just transition. Consistent with the study's methodological orientation, the findings are organised around key recurring themes generated from the interview data.

Awareness and Perceptions of 4IR Transport Innovations

The findings revealed a generally high level of awareness of Fourth Industrial Revolution (4IR) transport technologies among participants. Most respondents indicated that they were "very familiar" with the concept of 4IR technologies, while a smaller number described themselves as

"slightly familiar." Participants identified electric buses as the most visible and recognisable form of technological innovation within the institution's transport ecosystem. Some respondents also demonstrated awareness of additional innovations, such as GPS-based route-tracking systems and energy-efficient charging technologies.

Figure 1

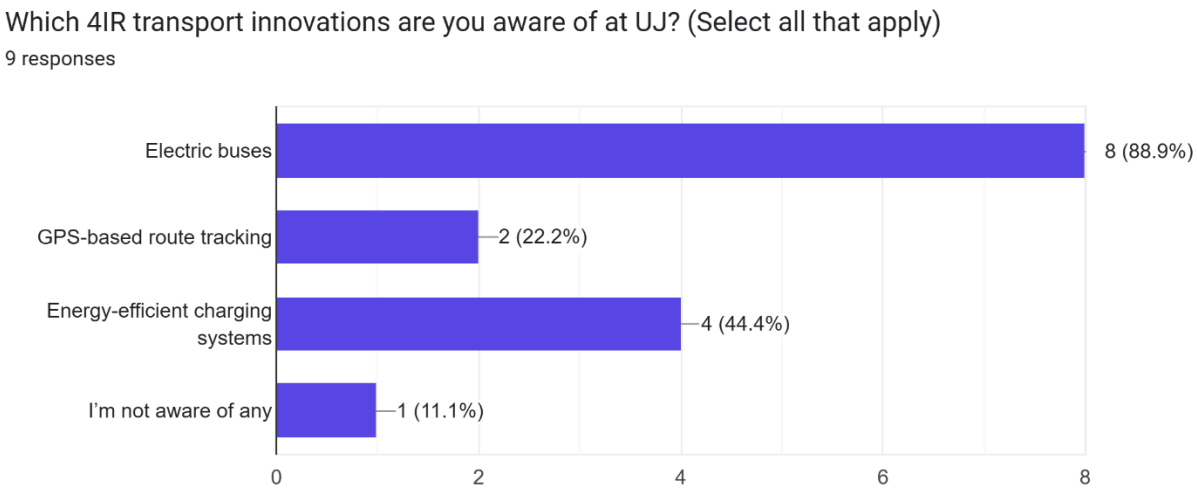


Figure 1 above suggests that electric buses have become symbolic representations of technological modernisation within the university environment. Participants frequently associated the buses with innovation, sustainability, efficiency, and institutional progress. One respondent explained that the electric buses had "made movement across campuses smoother and quieter," while another noted that the buses represented "improved productivity in a sustainable way." These responses indicate that users interpreted the innovation not merely as a transportation tool but as part of a broader institutional transition towards technologically enabled sustainability.

At the same time, the data also revealed uneven levels of awareness and engagement. One participant indicated that they were "not aware of any" 4IR transport innovations despite being associated with the institution. This suggests that while the innovation has achieved substantial visibility, communication gaps remain regarding broader institutional awareness and inclusion.

Improved Mobility Experience and Operational Efficiency

A dominant theme across the interviews was the perceived improvement in commuting experiences associated with the introduction of electric buses. Participants consistently described

the system as more efficient, comfortable, quieter, and less stressful compared to conventional transportation systems.

Several respondents emphasised the convenience of moving between campuses through the electric bus system. One participant stated that the buses had "eased the stress associated with commuting through public transport," while another explained that the innovation had made "moving across the campuses efficient." Others highlighted operational features such as quieter engines, smoother rides, and improved scheduling systems enabled by GPS tracking technologies.

Figure 2

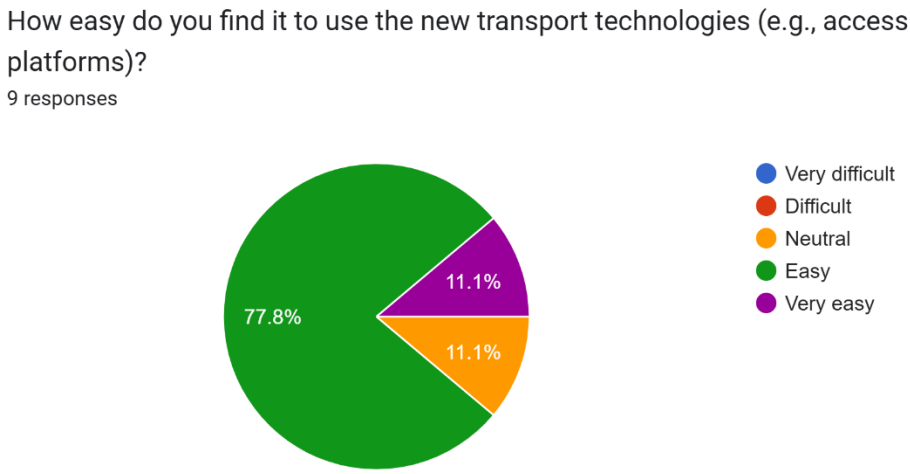
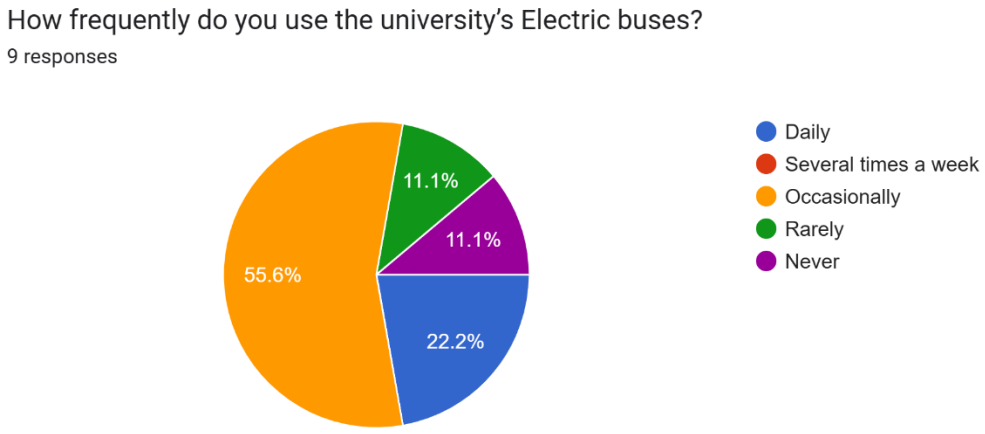


Figure 3



Both Figures 2 and 3 above suggest that electric buses contributed to improved time management and perceptions of productivity. Participants associated the buses with reduced commuting stress

and greater predictability within the university transport environment. In this regard, the innovation was perceived as enhancing both mobility and the overall quality of institutional life.

Importantly, participants also associated efficiency with technological sophistication. Features such as phone charging systems, digital coordination, and improved scheduling mechanisms were interpreted as indicators of a more modern transport ecosystem. This demonstrates how the electric buses functioned not only as vehicles but also as embodiments of a wider smart mobility transition.

Sustainability and Environmental Consciousness

Another major finding concerned participants' strong association between electric buses and environmental sustainability. Nearly all respondents believed that the introduction of electric buses had contributed positively to environmental protection and sustainable mobility practices within the institution.

Participants frequently linked the buses to reduced pollution, lower carbon emissions, noise reduction, and improved energy use. One respondent observed that the buses "significantly cut carbon emissions and reduce fuel dependency." At the same time, another highlighted that electric buses "do not use chemical fuel and hence do not produce greenhouse gases." Others pointed to reduced engine noise and cleaner commuting environments as important sustainability benefits.

These findings indicate that participants viewed the electric buses as contributing to a greener institutional environment and aligning with broader global sustainability goals. The buses were often interpreted as evidence of the university's commitment to climate-conscious development and innovation-driven sustainability.

At the same time, the findings suggest that environmental consciousness itself served as an important driver of technological acceptance. Many participants identified environmental sustainability as a key motivation for supporting and adopting the electric bus system. This reflects a growing awareness among users of the relationship between mobility systems and environmental responsibility.

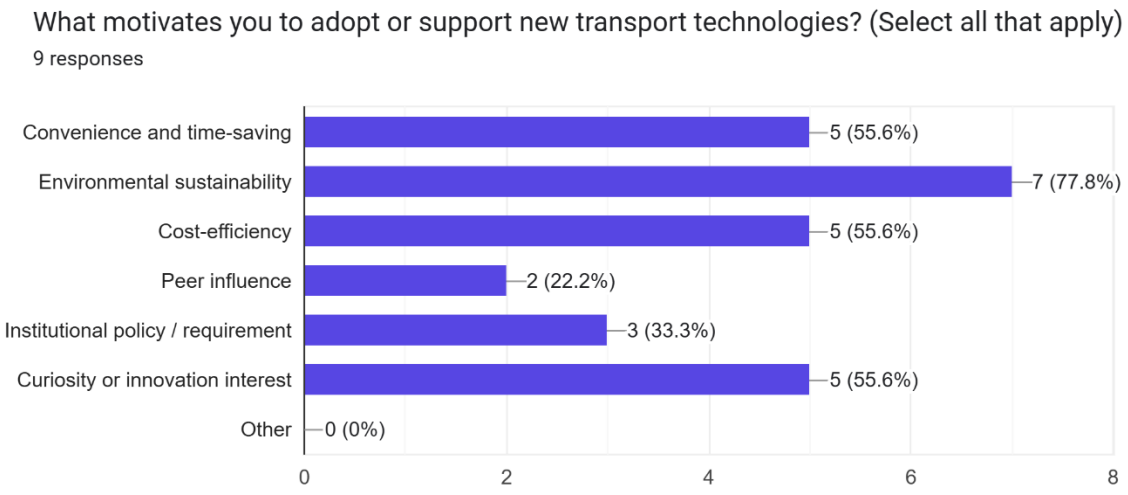
Motivations for Adoption and User Acceptance

The interviews revealed multiple factors influencing participants' willingness to adopt and support the electric bus system. Convenience and time-saving emerged as major motivations, with many respondents valuing the buses' efficiency and reliability.

Environmental sustainability also emerged strongly as a motivating factor. Participants expressed support for the innovation because of its perceived contribution to cleaner energy use and reduced

environmental degradation. Other motivations included cost-efficiency, institutional policy requirements, curiosity about innovation, and peer influence.

Figure 4



The Figure suggests that user acceptance was closely linked to perceptions of relative advantage and ease of use. Most participants described the buses as “easy” or “very easy” to use, suggesting low levels of technological complexity from the user perspective. This ease of use appears to have positively influenced adoption patterns and user satisfaction.

Barriers, Constraints, and Areas for Improvement

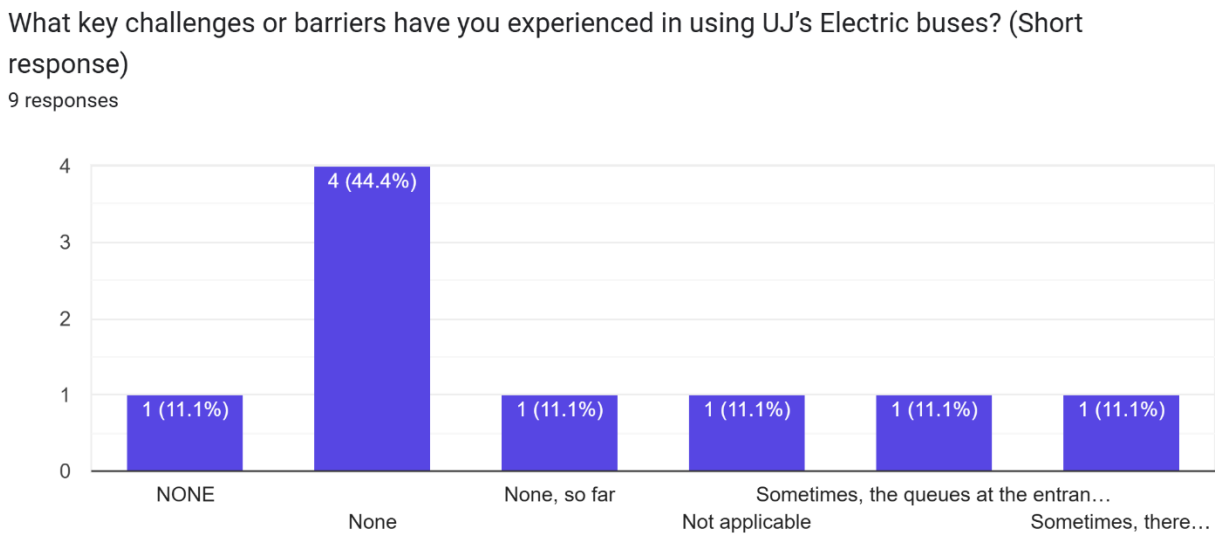
Despite the generally positive perceptions, participants also identified several challenges and limitations associated with the electric bus system. One recurring concern is related to limited bus availability during peak periods. Respondents noted that overcrowding and queues could become “physically and psychologically draining,” especially as demand for the buses increased.

Participants also noted occasional delays due to charging schedules and operational coordination. While these challenges were not viewed as severe enough to undermine support for the system, they highlighted important infrastructural and operational limitations within the existing mobility framework.

Another significant finding concerned the need for improved communication and digital integration. Several participants recommended introducing mobile applications with live bus tracking and estimated arrival times. Others proposed smarter timetable systems and stronger public awareness campaigns.

Additionally, some respondents emphasised the importance of technical capacity-building and maintenance infrastructure. One participant argued that institutional staff should receive specialised training to effectively maintain and repair electric vehicles. This reflects broader concerns regarding institutional readiness and the long-term sustainability of technological transitions. The figure below captures these challenges in users' lived experiences.

Figure 5



Overall, the findings demonstrate that while electric buses are widely perceived as beneficial and transformative, their continued success depends on addressing infrastructural, operational, communicative, and institutional challenges.

Discussion of Findings

The findings of this study reveal that electric buses, as a practical manifestation of Fourth Industrial Revolution (4IR) mobility innovation, are increasingly reshaping mobility experiences within the selected South African university context. Consistent with the study's theoretical framing, the diffusion and acceptance of electric buses were not determined solely by technical performance but by a combination of social perceptions, institutional support, infrastructural conditions, and sustainability consciousness. The findings, therefore, reinforce the argument that mobility transitions are fundamentally socio-technical processes rather than purely technological interventions.

A central finding of the study is the generally positive perception of electric buses among participants. Respondents consistently associated the buses with convenience, efficiency, reduced stress, environmental sustainability, and institutional modernisation. These findings strongly align with Rogers' Diffusion of Innovations theory, particularly the principle of relative advantage. According to Rogers (2003), innovations are more likely to be adopted when users perceive them as superior to existing alternatives. In this study, participants clearly perceived electric buses as offering advantages over conventional transport systems, including smoother mobility, quieter operation, cleaner energy use, and improved commuting experiences.

The findings also demonstrate that electric buses are increasingly understood not merely as transport technologies but as symbols of institutional transformation and sustainable development. Participants frequently connected the buses to broader ideas of innovation, climate responsibility, and modernisation. This supports arguments within the literature that 4IR technologies increasingly function as visible markers of institutional progress and smart urban development (Schwab, 2016). In this sense, the buses represent more than operational improvements; they embody a broader transition towards environmentally conscious, technologically integrated mobility systems.

Another important insight emerging from the findings concerns the relationship between electric mobility and sustainability consciousness. Most respondents strongly associated electric buses with reduced pollution, lower carbon emissions, noise reduction, and cleaner energy use. These findings align with existing studies on green mobility transitions, which argue that electric transportation systems contribute significantly to decarbonisation efforts and environmentally sustainable urban futures (Cervero, 2017). Importantly, however, the findings suggest that sustainability itself became a social motivation for adoption. Participants were not simply passive users of technology; many actively supported the innovation because they believed it contributed to climate protection and environmental responsibility.

This is particularly significant within the African urban context, where discussions of sustainable transport often remain secondary to concerns about accessibility and affordability. The findings therefore suggest the emergence of a growing environmental awareness among urban transport users, particularly within institutional spaces that actively promote sustainability agendas. The university environment appears to function as a diffusion space where technological and environmental norms reinforce one another.

The findings further reveal the importance of compatibility and ease of use in shaping user acceptance. Most respondents described the buses as easy or very easy to use, indicating low perceived complexity. Rogers' theory suggests that innovations diffuse more rapidly when they are compatible with existing user behaviours and when they do not require extensive technical adaptation. In this case, participants appeared to integrate electric buses into their everyday mobility routines relatively seamlessly. This ease of integration strengthened positive perceptions and increased willingness to support the innovation.

However, the findings also complicate simplistic techno-optimistic narratives surrounding 4IR mobility transitions. While participants overwhelmingly viewed the buses positively, they simultaneously identified important infrastructural and institutional constraints. Concerns about overcrowding during peak periods, charging system delays, and limited bus availability indicate that technological innovation alone cannot resolve broader mobility pressures without adequate infrastructure support.

This finding is particularly important because much of the global literature on smart mobility often assumes that technological efficiency automatically translates into improved urban transport outcomes. The present study, instead, demonstrates that the effectiveness of mobility innovation depends heavily on the institutional and infrastructural environment in which it operates. Electric buses may improve mobility experiences, but their transformative potential remains limited if supporting systems such as charging infrastructure, maintenance capacity, route management, and operational scaling remain underdeveloped.

The findings also highlight the importance of communication and institutional awareness in shaping diffusion processes. Although most participants were aware of the electric buses, some demonstrated limited awareness of the broader 4IR transport ecosystem within the university. One participant explicitly stated that they were unaware of any transport innovations, despite being associated with the institution. This suggests that diffusion is uneven and mediated by communication channels, institutional engagement, and user networks.

This observation reinforces Rogers' emphasis on communication as a critical component of innovation diffusion. Technologies do not diffuse automatically simply because they exist; their adoption is shaped by how they are communicated, interpreted, and socially validated. In this study, users who appeared more informed about the innovation also demonstrated stronger perceptions of its value and sustainability implications. Consequently, institutional awareness

campaigns and user engagement strategies become crucial components of successful mobility transitions.

The study additionally reveals that users increasingly expect digital integration and smart functionality within transport systems. Several participants recommended real-time tracking applications, smart timetable systems, and enhanced digital coordination mechanisms. These expectations illustrate how users now associate mobility innovation with intelligent connectivity and data-driven efficiency rather than merely vehicle electrification. This finding reflects broader transformations associated with the 4IR, where digital technologies, data systems, and mobility infrastructures increasingly converge to produce integrated smart transport ecosystems.

Importantly, the findings also foreground questions of institutional readiness and long-term sustainability. Participants highlighted the need for specialised technical training and maintenance capacity to ensure the long-term viability of electric bus systems. This aligns with critical scholarship arguing that technological transitions require more than infrastructure investment; they also depend on human capacity development, governance readiness, and institutional adaptation (Pojani & Stead, 2018). In many African contexts, technological systems often fail not because the technologies themselves are ineffective but because supporting maintenance structures and technical expertise remain inadequate.

The findings therefore support the study's broader argument that mobility innovation must be understood as a socio-technical transition rather than a purely technological intervention. Electric buses operate within broader systems involving governance structures, user trust, institutional culture, infrastructural capacity, sustainability norms, and everyday mobility practices. Their success depends on how effectively these dimensions align.

Furthermore, the findings underscore the significance of universities as experimental spaces for mobility innovation. The selected institution served as a relatively controlled environment in which electric mobility technologies could be introduced, tested, and socially negotiated. Universities often possess greater institutional flexibility, stronger sustainability agendas, and higher levels of innovation acceptance than many broader urban systems. As such, they can serve as important laboratories for testing sustainable mobility transitions before wider urban implementation.

Nevertheless, the study also raises important questions about scalability. While electric buses appear effective within the university environment, scaling such systems across Johannesburg's broader transport landscape would involve significantly more complex political, infrastructural,

and economic challenges. Public transport systems in Johannesburg remain shaped by fragmentation, inequality, informality, and uneven infrastructural development. Consequently, replicating university-level mobility success at a city-wide scale would require substantial investment, integrated planning, policy coordination, and stakeholder collaboration.

Ultimately, the findings demonstrate that electric buses possess significant potential to contribute to the transition from urban gridlock to green flow within African urban contexts. However, this potential is neither automatic nor guaranteed. The transformative capacity of electric mobility depends on sustained institutional commitment, infrastructural investment, user acceptance, effective communication, and broader governance support. In this regard, the study contributes to emerging debates on sustainable urban mobility by showing that technological innovation alone cannot produce just urban transitions unless embedded within inclusive, context-sensitive, and institutionally supported mobility frameworks.

Conclusion

This study has demonstrated that electric buses, as a practical manifestation of Fourth Industrial Revolution (4IR) mobility innovation, possess significant potential to reconfigure urban mobility systems within African cities. Moving beyond abstract discussions of smart technologies, the research grounded the 4IR debate within the lived realities of Johannesburg's transport challenges by examining how electric mobility is experienced, interpreted, and negotiated within a South African university context. The findings reveal that electric buses are not merely technological upgrades to existing transport systems; they represent broader socio-technical transitions that intersect with sustainability, institutional transformation, user behaviour, and questions of urban justice.

The study found that participants overwhelmingly perceived electric buses as improving mobility efficiency, reducing commuting stress, enhancing environmental sustainability, and symbolising institutional modernisation. In doing so, the research confirms that the adoption of mobility innovations is shaped not only by technical functionality but also by social meaning, institutional trust, and perceptions of relative advantage. Electric buses became visible embodiments of a greener and smarter urban future, reinforcing the argument that technological transitions are deeply embedded in processes of social acceptance and meaning-making.

Crucially, the findings also provide important insights into the question of a just urban transition. Within the institutional setting examined, the introduction of electric buses did not appear to widen

social or economic inequalities among users significantly. Participants generally perceived the system as accessible, beneficial, and collectively advantageous across different categories of commuters. The buses reduced mobility stress, improved predictability, and enhanced access to institutional spaces in ways that many users associated with inclusion rather than exclusion. However, the study also reveals that justice in mobility transitions cannot be assumed. The relative inclusiveness observed within the university environment was made possible by institutional support structures, subsidised access, and controlled operational conditions that may not easily translate into wider urban contexts.

The findings, therefore, caution against overly techno-optimistic assumptions about the transformative power of 4IR technologies. While electric buses improved mobility experiences within the selected institutional setting, their effectiveness remained constrained by infrastructural limitations, operational pressures, communication gaps, and concerns about long-term maintenance capacity. More importantly, scaling such systems across Johannesburg's fragmented and unequal urban transport landscape may risk reproducing new forms of exclusion if issues of affordability, accessibility, infrastructure distribution, and policy coordination are not deliberately addressed.

Ultimately, the transition from gridlock to green flow in African cities is not simply about adopting cleaner technologies but about reimagining mobility through the interconnected lenses of sustainability, inclusion, accessibility, and justice. Electric buses offer an important pathway towards environmentally sustainable and technologically integrated urban futures. However, their transformative potential will only be realised when innovation is embedded within context-sensitive, socially inclusive, and institutionally supported mobility frameworks. In this regard, the study contributes to emerging Global South debates by demonstrating that a truly just urban transition requires not only green technologies but also equitable systems that ensure the benefits of mobility transformation are broadly shared rather than unevenly distributed.

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Appendix:

Interview Guide/Instrument

Section 1: Participant Demographics

(Purpose: To understand the diversity of transport users at UJ)

1. **What is your gender?**
    - Male
    - Female
    - Non-binary / Prefer not to say
2. **Which category best describes you?**
    - Undergraduate student
    - Postgraduate student
    - Postdoctoral fellow
    - Academic staff
    - Administrative staff
    - Contractor / Service provider
    - Other (please specify)
3. **What is your age group?**
    - Under 25 years
    - 25–34 years
    - 35–44 years
    - 45–54 years
    - 55 years and above
4. **How long have you been associated with the University of Johannesburg?**
    - Less than 1 year
    - 1–3 years
    - 4–6 years
    - Over 6 years
5. **How frequently do you use the university's transport services (e.g., electric buses or shuttles)?**
    - Daily
    - Several times a week
    - Occasionally
    - Rarely
    - Never

Section 2: Awareness and Perceptions of 4IR Technologies

(Purpose: To measure user awareness, attitudes, and perceived benefits)

6. **How familiar are you with the term "Fourth Industrial Revolution (4IR) technologies"?**
    - Not at all familiar

- Slightly familiar
- Moderately familiar
- Very familiar

7. **Which 4IR transport innovations are you aware of at UJ?** *(Select all that apply)*
   - Electric buses
   - Smart ticketing / contactless payment
   - GPS-based route tracking
   - Mobile app for transport updates
   - Energy-efficient charging systems
   - I am not aware of any
8. **How has the use of these technologies affected your commuting experience within the university?**
   (Short paragraph response)
9. **Do you believe that 4IR transport technologies have made UJ's transport system more sustainable (e.g., less pollution, better energy use)? Why or why not?** *(Paragraph response)*

Section 3: Diffusion, Adoption, and Engagement

(Purpose: To understand adoption patterns, communication, and user behaviour)

10. **How would you rate UJ's communication and awareness campaigns about these transport innovations?**
    - Very poor
    - Poor
    - Average
    - Good
    - Excellent
11. **How easy do you find it to use the new transport technologies (e.g., accessing buses, digital platforms, or payment systems)?**
    - Very difficult
    - Difficult
    - Neutral
    - Easy
    - Very easy
12. **What motivates you to adopt or support new transport technologies?** *(Select all that apply)*
    - Convenience and time-saving
    - Environmental sustainability
    - Cost-efficiency
    - Peer influence
    - Institutional policy/requirement
    - Curiosity or innovation interest

- Other (please specify)

13. **What key challenges or barriers have you experienced in using UJ's Electric buses?**
    (Short paragraph response)

Section 4: Future Outlook and Broader Impact

(Purpose: To explore improvement strategies and broader policy relevance)

14. **In your opinion, what additional innovations could improve the university's electric buses?**
    (Short answer)
15. **How can UJ's approach to using 4IR technologies in transportation serve as a model for other African Universities or Cities?**

5: Consent

16. **Do you consent to participate in this interview anonymously, with your responses used solely for academic research purposes?**
    - Yes, I consent
    - No, I do not consent