



Evaluating the potential of electric buses in eThekweni Municipality KwaZulu-Natal public transport network

by

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ABSTRACT

This study examines the feasibility of integrating electric buses into the eThekweni Municipality's public transport network in KwaZulu-Natal, South Africa. The research explores the technical, economic, environmental, and policy dimensions of transitioning from diesel to electric buses within a developing urban context. A qualitative case study design was employed, focusing on Go Durban, the city's main public transport operator. This study involved 20 participants from the eThekweni Municipality's public transport ecosystem, including 7 transport officials, 5 fleet managers, 3 policy experts, and 5 commuters. This diversity ensures a comprehensive understanding of perspectives on integrating electric buses into the public transport network. Data were collected through semi-structured interviews, focus groups, observations, and document analysis, and were analysed thematically using Braun and Clarke's six-phase framework.

Findings revealed that while electric buses offer substantial environmental benefits through reduced greenhouse gas emissions and improved air quality, several barriers persist. Technical challenges include limited battery performance under humid and hilly conditions, as well as inadequate charging infrastructure. Economic feasibility is constrained by high capital costs and uncertain funding mechanisms, though long-term savings and employment opportunities offer promise. Environmentally, the benefits are moderated by South Africa's coal-dependent electricity supply, raising questions about the net reduction in carbon emissions. Policy gaps, fragmented regulatory frameworks, and limited institutional coordination further hinder large-scale implementation.

The study recommends targeted incentives, integrated policy reforms, investment in renewable energy-based charging systems, and strengthened public-private partnerships to support the sustainable electrification of public transport. Overall, the research underscores the importance of aligning technological innovation with economic viability, environmental responsibility, and governance readiness to

achieve a resilient and sustainable transport future for eThekweni Municipality and similar urban contexts in the Global South.

Keywords: Electric buses, eThekweni Municipality, sustainability, qualitative research, transport policy, South Africa.

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LIST OF ACRONYMS

BRT	Bus Rapid Transit
CO ₂	Carbon Dioxide
DoT	Department of Transport
eThekwini	eThekwini Municipality (Durban Metropolitan Area)
EV	Electric Vehicle
EIA	Environmental Impact Assessment
GHG	Greenhouse Gas
Go! Durban	eThekwini's Integrated Public Transport Network
GWh	Gigawatt Hour
ICT	Information and Communication Technology
IPCC	Intergovernmental Panel on Climate Change
KZN	KwaZulu-Natal
LED	Light Emitting Diode
NDP	National Development Plan
NO _x	Nitrogen Oxide
OEM	Original Equipment Manufacturer
POPIA	Protection of Personal Information Act
PPP	Public-Private Partnership
RE	Renewable Energy
ROI	Return on Investment
SMME	Small, Medium and Micro Enterprise
SRT	Sustainable Rapid Transit
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organization

CHAPTER 1: INTRODUCTION

1.1 Background

Electric buses have emerged as a key strategy for decarbonising urban transport systems as public transportation networks globally transition towards electric mobility. The integration of electric buses into public networks has become increasingly important in the eThekweni Municipality, KwaZulu-Natal Public Transport Network, where road transport accounts for approximately 10% of greenhouse gas (GHG) emissions (Nkomo & Fletcher, 2021). However, this transition faces significant challenges related to technology preparedness, policy coherence, and economic constraints (Van der Merwe & Van Niekerk, 2020).

Anderson and Raskin (2021) observed that despite global advancements in electric bus technology and economics, specific constraints within South Africa currently limit widespread adoption. The energy grid's reliance on coal-based electricity generation poses a particular challenge to this green transition, potentially diminishing the net environmental benefits of electric bus operations (Stone, 2019). Nevertheless, the imperative to fulfil climate commitments and improve urban air quality standards keeps public transport electrification high on the national policy agenda.

Despite their potential benefits, electric buses require sophisticated infrastructure and operational systems that differ substantially from conventional diesel fleets. The eThekweni Municipality's geography and climate, particularly its hilly terrain, present constraints on battery efficiency and vehicle range (Zhang et al., 2020). Many metropolitan areas lack adequate charging infrastructure, thereby impeding the deployment of electric bus systems (Gupta & Bose, 2020). These practical challenges are compounded by fragmented regulatory frameworks that lack clarity and sufficient incentives to encourage investment in electric bus systems (Nkomo & Fletcher, 2021). Hook et al. (2020) warn that without coherent national alignment between energy and transport policies, the electric mobility sector will remain fragmented. Thus, any transition strategy must account for local topographical, institutional, and infrastructural characteristics rather than simply replicating global success narratives.

Electric buses present both socio-economic opportunities and trade-offs. These vehicles may substantially reduce long-term maintenance and operational expenditures for urban transit authorities (Anderson & Raskin, 2021). However, the substantial initial capital investment required for electric fleets and associated infrastructure—including charging stations and specialized maintenance depots—presents a formidable barrier for many municipalities (Bohnsack et al., 2020). As Venter (2021) observed, considerations of equity in access to clean transport must be carefully addressed, particularly for underserved populations. While Jackson and Young (2019) argue that electric buses reduce noise pollution and mitigate health concerns in densely populated urban areas, skeptics question whether these benefits extend equitably to marginalized passengers. This tension underscores the need for an inclusive and cost-sensitive planning approach when assessing the social impact and feasibility of electric bus adoption in South Africa.

1.2 Research Problem

Ideally, eThekweni Municipality should operate a public transport network that is environmentally sustainable, economically viable, and socially inclusive, thereby contributing to national climate goals as articulated in the National Development Plan (NDP) 2030 and the United Nations Sustainable Development Goals (SDGs). However, the current reality is that the municipality's bus fleet remains heavily reliant on diesel-powered vehicles, which generate significant greenhouse gas emissions, degrade urban air quality, and incur escalating operational costs due to volatile fuel prices.

While there is growing interest in electric bus technology as a potential solution, there exists no systematic, context-specific evaluation of the technical feasibility, economic implications, environmental benefits, and policy requirements necessary to inform a successful transition. The consequences of this gap are severe: continued environmental degradation undermines public health and climate commitments; uncertain economic returns deter investment and limit the municipality's capacity to scale sustainable transport solutions; and the absence of clear policy guidance hinders coordinated action among government stakeholders, operators, and financiers.

This study therefore seeks to address these deficiencies by comprehensively evaluating the potential of electric buses within eThekweni Municipality's public transport network, thereby providing evidence-based recommendations to support sustainable urban mobility transformation.

1.3 Aim of the Study

The aim of this study is to comprehensively evaluate the potential of integrating electric buses into the eThekweni Municipality's public transport network, with specific attention to technical, economic, environmental, and policy dimensions.

The national government should introduce focused fiscal support measures—such as capital grants, tax incentives, and concessional financing—to help municipalities and transport operators manage the higher initial costs associated with procuring electric buses and developing charging infrastructure. This would improve the long-term financial sustainability of environmentally friendly public transport systems.

1.4 Research Objectives

1.4.1 Main Research Objective

To assess the feasibility and implications of adopting electric buses in the eThekweni Municipality's public transport system.

1.4.2 Sub Research Objectives

- To evaluate the technical viability and operational performance of electric buses in the eThekweni context, accounting for local climate and topography.
- To examine the economic feasibility and cost implications of transitioning from diesel to electric bus fleets, including capital and operational expenditures.
- To assess the environmental impact and sustainability benefits of electric bus adoption, considering South Africa's current energy generation mix.
- To identify policy and regulatory frameworks required to support the successful integration of electric buses into eThekweni's transport network.

1.5 Research Questions

1.5.1 Main Research Question

What is the potential for adopting electric buses in the eThekweni Municipality's public transport network?

1.5.1 Sub Research Questions

- How viable are electric buses technically and operationally within eThekweni's specific climate and topographical conditions?
- What are the economic implications and cost structures associated with adopting electric buses compared to conventional diesel fleets?
- What environmental benefits and challenges emerge from electric bus adoption in the context of South Africa's coal-dependent energy system?
- What policy frameworks and regulatory measures are necessary to facilitate successful electric bus integration?

1.6 Study Purpose and Value

This study seeks to generate evidence-based insights that can inform strategic decision-making by eThekweni Municipality, the KwaZulu-Natal Department of Transport, and other stakeholders involved in public transport planning and policy development. By providing a comprehensive evaluation of the technical, economic, environmental, and policy dimensions of electric bus adoption, the research aims to contribute to South Africa's broader sustainable transport agenda and climate mitigation efforts.

The value of this research extends beyond eThekweni Municipality to other South African cities and African metropolitan areas facing similar challenges in transitioning to sustainable public transport systems. The study's contextualized findings will support more informed investment decisions, policy formulation, and operational planning for electric bus systems in resource-constrained urban environments.

1.7 Study Site

This study focuses on the eThekweni Municipality, which encompasses the greater Durban metropolitan area in KwaZulu-Natal province, South Africa. With a population of approximately 3.9 million residents, eThekweni is the country's third-largest metropolitan municipality and a critical economic hub for the region. The municipality operates the Go Durban integrated public transport system, which serves as the primary case study for this research. The city's unique characteristics—including its subtropical climate, hilly coastal

topography, and diverse socio-economic demographics—provide a valuable context for evaluating electric bus feasibility in a Global South urban setting.

1.8 Research Methodology

This study employs a qualitative case study research design, grounded in an interpretivist paradigm. Data were collected through semi-structured interviews with 20 stakeholders, including transport policy officials (n=7), fleet managers (n=5), policy experts (n=3), and regular commuters (n=5). Additional data sources included focus group discussions, direct observations of bus depot operations and charging facilities, and documentary analysis of policy documents and operational reports. Thematic analysis, following Braun and Clarke's (2006) six-phase framework, was employed to identify, analyze, and report patterns within the data. The study was approved by the University of KwaZulu-Natal's Research Ethics Committee and adhered to all ethical protocols, including informed consent and participant confidentiality.

1.9 Significance of the Study

This research contributes to the scholarly literature on sustainable urban transport in developing economies by providing empirical evidence on electric bus adoption in a South African context. The study addresses critical gaps in the existing literature, which predominantly focuses on high-income countries with well-established charging infrastructure and supportive policy environments. By examining the unique challenges and opportunities presented by eThekweni's operational context, this research offers actionable insights for policymakers, transport planners, and municipal authorities across the African continent.

Furthermore, the study's integration of technical, economic, environmental, and policy perspectives provides a holistic evaluation framework that can be adapted and applied to other urban transit contexts in the Global South. The findings will support evidence-based decision-making and contribute to South Africa's commitments under the Paris Agreement, the Sustainable Development Goals, and the National Development Plan 2030.

1.10 Organisation of Chapters 1-5

This dissertation is organized into five chapters. Chapter 1 provides an introduction to the study, including the background, problem statement, research objectives and questions, and an overview of the methodology. Chapter 2 presents a comprehensive review of the literature on electric bus adoption, covering technical, economic, environmental, and policy dimensions, and establishes the theoretical frameworks guiding the study. Chapter 3 details the research design and methodology, including the research paradigm, sampling strategy, data collection methods, and analytical approach. Chapter 4 presents and discusses the research findings, organized thematically to address each research objective. Finally, Chapter 5 summarizes the key findings, articulates the study's contribution to knowledge, and provides practical recommendations for policymakers, transport authorities, and other stakeholders.

1.11 Preview of Literature Review and Theoretical Framework

Chapter 2 provides a comprehensive review of literature pertaining to electric bus adoption in urban public transport systems, with particular emphasis on technical viability, economic feasibility, environmental sustainability, and policy frameworks. The theoretical foundation of this study draws primarily on the Technology Acceptance Model (TAM) developed by Davis (1989) and the Diffusion of Innovations (DOI) theory proposed by Rogers (2003). Together, these frameworks offer a robust lens for understanding the factors that facilitate or inhibit the adoption of new transport technologies in emerging economies. TAM explains how stakeholders evaluate new technology based on perceived usefulness and ease of use, while DOI theory examines how innovations spread through social systems over time. These theoretical frameworks inform the research design and guide the interpretation of findings in subsequent chapters.

1.12 Chapter Summary

This chapter introduced the study's background, highlighting the growing importance of electric bus adoption as a strategy for sustainable urban transport. The research problem was articulated using a three-part structure that identified the ideal situation (sustainable, low-emission public transport), the actual situation (continued reliance on diesel buses), and the consequences of this gap (environmental degradation, economic uncertainty, and policy incoherence). The chapter established the research aim, objectives, and questions that guide the investigation, and outlined the study's purpose, value, and significance. The research methodology was briefly introduced, and the organization of subsequent chapters was previewed. The chapter concluded by foreshadowing the literature review and theoretical frameworks that underpin the study, setting the stage for a comprehensive evaluation of electric bus potential in eThekweni Municipality.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The transition from conventional diesel-powered buses to electric buses (EBs) is increasingly recognised as a critical step toward sustainable urban mobility. For developing contexts such as eThekweni Municipality in KwaZulu-Natal, South Africa, this transition poses multiple technical, economic, environmental, and policy challenges. The purpose of this chapter is to synthesise global and local literature in relation to the study's objectives and questions.

This literature review is situated within broader policy frameworks that emphasize sustainable development. The United Nations Sustainable Development Goals (SDGs), particularly SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action), provide the global context for urban transport electrification (United Nations, 2015). At the national level, South Africa's National Development Plan (NDP) 2030 identifies sustainable transport as essential for economic growth, social inclusion, and environmental protection (National Planning Commission, 2012). The Department of Transport's Green Transport Strategy (2018) specifically calls for the integration of low-emission vehicles into public transport fleets. At the municipal level, eThekweni's Integrated Development Plan (IDP) 2022-2027 commits to reducing greenhouse gas emissions by 40% by 2030 and improving air quality in urban corridors (eThekweni Municipality, 2022).

The review addresses four focal areas: (i) technical viability and operational performance; (ii) economic feasibility and cost implications; (iii) environmental sustainability and social impact; and (iv) policy and regulatory frameworks supporting electric mobility. The chapter concludes with an integrated conceptual framework linking the reviewed literature to the study's research objectives.

2.2 Theoretical Framework

This study is anchored in two complementary theoretical frameworks: the Technology Acceptance Model (TAM) and Diffusion of Innovations (DOI) theory. These frameworks provide a robust lens through which to examine the adoption of electric bus technology in eThekweni Municipality's public transport network.

2.2.1 Technology Acceptance Model (TAM)

The Technology Acceptance Model, developed by Davis (1989), posits that perceived usefulness and perceived ease of use are primary determinants of technology adoption. In the context of electric buses, these constructs relate to stakeholder beliefs about operational efficiency, cost-effectiveness, environmental benefits, and system manageability. Several studies have successfully applied TAM to transport technology adoption, demonstrating its relevance to infrastructure-dependent innovations (Venkatesh & Davis, 2000; Wang et al., 2019).

2.2.2 Diffusion of Innovations (DOI) Theory

Rogers' (2003) Diffusion of Innovations theory explains how, why, and at what rate new technologies spread through social systems. The theory identifies five key attributes influencing adoption: relative advantage, compatibility, complexity, trialability, and observability. Together, TAM and DOI provide a comprehensive framework for understanding both individual acceptance decisions and system-level diffusion processes in electric bus adoption.

2.3 Technical Viability and Operational Performance of Electric Buses

Research Question 1: What are the specific technical challenges associated with the operational efficiency of electric buses in eThekweni Municipality's diverse environmental conditions?

Electric bus technology has advanced globally, yet success depends on local environmental, infrastructural, and operational factors. Studies demonstrate that climatic conditions, particularly high humidity and steep topography, significantly affect battery range and efficiency (Bohnsack et al., 2020; Schäfer, 2019; Zhang et al., 2020). Infrastructure limitations, including underdeveloped charging networks and coal-dependent electricity grids, further constrain technical feasibility in South African contexts (Nkomo & Fletcher, 2021).

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2.4 Economic Feasibility and Cost Implications

Research Question 2: What are the initial and long-term economic costs and benefits of replacing traditional diesel buses with electric buses in eThekweni Municipality?

Economic feasibility remains contentious in developing economies. High upfront capital costs—often double those of diesel buses—create significant barriers (Anderson & Raskin, 2021). However, long-term operational savings through reduced fuel and maintenance costs offer partial cost recovery, with breakeven periods of 8-10 years in well-managed systems (Morris & Sullivan, 2018). Innovative financing mechanisms, including green bonds, public-private partnerships, and international

climate finance, have proven essential for successful adoption in resource-constrained contexts (Meyer et al., 2016).

2.5 Environmental Sustainability and Social Impact

Research Question 3: How do electric buses contribute to environmental sustainability and address public health concerns related to air quality in eThekweni Municipality?

Electric buses eliminate tailpipe emissions, potentially reducing urban air pollution by 30-50% in high-density corridors (Li et al., 2019). However, environmental benefits are moderated by electricity generation sources. In coal-intensive grids like South Africa's, lifecycle emissions reductions are attenuated to 20-30% compared to diesel buses, versus 80%+ reductions in renewable energy contexts (Harris & Thompson, 2020; Stone, 2019). Noise pollution reduction and social equity considerations represent additional environmental justice dimensions requiring careful route planning (Brooks & Goss, 2018; Van der Merwe & Van Niekerk, 2020).

2.6 Policy and Regulatory Frameworks Supporting Electric Mobility

Research Question 4: What policy and institutional frameworks are necessary to facilitate the successful integration of electric buses into eThekweni Municipality's public transport system?

Policy coherence and institutional coordination are critical enablers of electric mobility transitions. International evidence demonstrates that successful adoption requires multi-level governance structures aligning national energy, transport, and climate policies with municipal operational realities (Hook et al., 2020). Fragmented regulatory frameworks, unclear charging infrastructure standards, and limited integration between transport and energy planning processes create significant barriers in South African contexts (Nkomo & Fletcher, 2021; Van der Merwe & Van Niekerk, 2020).

2.7 Research Gap: Identifying the Knowledge Lacuna

Despite the growing body of literature on electric bus adoption globally, significant knowledge gaps persist regarding the feasibility and implementation pathways in developing urban contexts, particularly in sub-Saharan Africa. This section explicitly articulates the research lacunae that this study addresses, organized thematically to correspond with the four focal areas of the literature review.

2.7.1 Geographical and Contextual Gaps

The overwhelming majority of electric bus research focuses on high-income countries (China, Europe, North America) or emerging economies with established manufacturing capacity and policy frameworks (India, Latin America). Studies examining electric bus adoption in African contexts remain scarce, with virtually no peer-reviewed research specifically addressing South African municipalities' experiences. This geographical bias creates three specific knowledge gaps:

First, existing literature provides limited evidence on electric bus performance in climatic conditions characteristic of coastal sub-Saharan African cities—specifically, the combination of high humidity (70-85% year-round), subtropical temperatures (15-30°C), and moderate topographical variation. While studies address extreme cold (Scandinavia) or extreme heat (Middle East) separately, the humid subtropical conditions of cities like eThekweni remain under-researched. Consequently, battery degradation rates, thermal management requirements, and range performance under these specific conditions are poorly understood.

Second, South Africa's unique energy context—heavy reliance on coal-generated electricity (approximately 80% of the grid) combined with ambitious renewable energy targets—creates a distinctive lifecycle emissions profile that existing literature does not adequately address. Most studies assume either fully renewable grids or stable fossil fuel mixes, but South Africa's transitional energy system presents novel challenges and opportunities for electric bus environmental accounting that have not been systematically examined.

Third, the institutional and governance context of South African municipalities—characterized by capacity constraints, intergovernmental coordination challenges, and fiscal pressures—differs substantially from the contexts examined in existing literature.

The applicability of policy recommendations derived from Chinese centralized planning models or European well-resourced municipalities to South African contexts remains largely untested.

2.7.2 Methodological and Theoretical Gaps

Existing electric bus literature exhibits two significant methodological limitations. First, most studies employ quantitative modelling approaches (lifecycle assessments, techno-economic simulations, optimization algorithms) that, while valuable for technical feasibility analysis, provide limited insight into stakeholder perceptions, institutional barriers, and socio-political dimensions of adoption. Qualitative case studies examining multi-stakeholder perspectives within specific municipal contexts remain rare, particularly in developing economies.

Second, theoretical frameworks in the electric bus literature are often implicit or absent. While technical and economic analyses dominate, few studies explicitly ground their investigations in established technology adoption theories. The application of Technology Acceptance Model (TAM) and Diffusion of Innovations (DOI) theory to electric bus adoption in public transport systems, particularly in developing contexts, represents an under-explored theoretical avenue. This study addresses this gap by explicitly operationalizing TAM and DOI constructs to understand stakeholder acceptance and system-level diffusion barriers.

2.7.3 Technical Knowledge Gaps Specific to eThekweni's Context

While general technical challenges of electric bus operation are well-documented, context-specific evidence for eThekweni Municipality is absent. Specifically:

1. The impact of eThekweni's hilly topography (elevations ranging from sea level to 600+ meters) on battery performance and energy consumption patterns remains undocumented. Existing studies from hilly cities focus primarily on temperate climates (San Francisco, Zurich) rather than humid subtropical contexts.
2. Charging infrastructure requirements for eThekweni's specific route network, considering Go Durban's operational schedules, peak demand periods, and spatial distribution of depots, have not been systematically assessed. Generic

infrastructure planning guidelines derived from other contexts may not translate effectively.

3. The interaction between eThekweni's electrical grid capacity, load-shedding vulnerabilities, and electric bus charging demands represents a critical operational risk that has not been empirically examined. This gap is particularly significant given South Africa's ongoing electricity supply challenges.
4. Technical training requirements and maintenance capacity needs for electric buses in South African contexts, where high-voltage vehicle expertise is limited and technician certification programs are nascent, remain poorly understood.

2.7.4 Economic and Financial Analysis Gaps

Economic analyses of electric bus adoption in developing contexts exhibit several limitations:

First, total cost of ownership (TCO) calculations in existing literature often rely on assumptions derived from high-income contexts—stable electricity prices, predictable maintenance costs, established resale markets for used vehicles and batteries. These assumptions may not hold in South African contexts characterized by electricity price volatility, limited electric vehicle servicing capacity, and absent secondary markets for electric bus components.

Second, innovative financing mechanisms suitable for resource-constrained municipalities remain under-explored. While public-private partnerships (PPPs) and green bonds are frequently recommended, detailed feasibility assessments, risk-sharing arrangements, and implementation pathways specific to South African municipal contexts are lacking in the literature.

Third, the economic implications of phased versus full-scale deployment strategies in medium-sized developing economy cities (like eThekweni, with approximately 600,000 daily public transport trips) have not been comparatively analyzed. Optimal fleet transition strategies considering budgetary constraints, operational continuity, and learning curve effects remain unclear.

2.7.5 Policy and Governance Gaps

Policy research on electric mobility in South Africa identifies general barriers (fragmented governance, unclear regulations, limited incentives) but lacks detailed, municipality-specific analysis of:

1. The specific regulatory obstacles faced by municipal transport authorities in procuring, deploying, and operating electric buses under current South African legislation and procurement frameworks.
2. Coordination mechanisms between national (Department of Transport, Department of Energy), provincial, and municipal actors that would enable effective electric bus policy implementation. Existing literature acknowledges coordination challenges but provides limited evidence on functional coordination models applicable to South African governance structures.
3. The role of local political economy factors—including labor union positions on technology transitions, local manufacturing interests, and political commitment cycles—in shaping electric bus adoption trajectories. These factors, well-documented in industrial transition literature, remain under-examined in the electric mobility context.
4. Community engagement strategies and public acceptance dynamics specific to electric bus introduction in South African townships and peri-urban areas, where trust in municipal services may be limited and historical patterns of service delivery failures shape stakeholder perceptions.

2.7.6 Practical and Operational Knowledge Gaps

Finally, the literature provides limited guidance on practical operational challenges that municipal transport managers and fleet operators encounter during electric bus transitions. Specifically:

Driver training programs, behavioural adaptation requirements, and workforce transition management strategies for electric bus fleets remain inadequately documented, particularly regarding drivers' experiences with regenerative braking, range anxiety management, and charging protocols.

Maintenance workflow redesigns, spare parts supply chain establishment, and warranty management practices for electric buses in contexts distant from

manufacturing hubs (Europe, China) lack systematic documentation. The practical realities of obtaining technical support, managing battery warranties, and coordinating with original equipment manufacturers (OEMs) across time zones and regulatory jurisdictions represent operational challenges absent from most academic literature.

Performance monitoring frameworks, key performance indicators (KPIs), and evaluation methodologies appropriate for assessing electric bus pilot projects in developing economy municipalities have not been standardized. Existing frameworks often emphasize metrics relevant to high-income contexts (carbon footprint reduction, total cost of ownership) while underemphasizing concerns critical to resource-constrained settings (service reliability, affordability, employment impacts).

2.7.7 Summary: The Specific Research Gap This Study Addresses

In summary, this study addresses a critical knowledge lacuna at the intersection of sustainable transport, technology adoption, and urban governance in developing African contexts. Specifically, the research fills the gap by:

1. Providing the first comprehensive, multi-stakeholder qualitative analysis of electric bus feasibility in a South African municipality, examining technical, economic, environmental, and policy dimensions through the lens of TAM and DOI theory.
2. Generating context-specific empirical evidence on electric bus performance under eThekweni's unique climatic, topographical, and infrastructural conditions, addressing the geographical knowledge gap in existing literature.
3. Examining stakeholder perceptions, institutional barriers, and socio-political factors influencing adoption, addressing the methodological gap toward quantitative-dominated research.
4. Developing practical insights and operational guidance grounded in lived experience of transport officials, fleet managers, and users, addressing the implementation knowledge gap.
5. Contributing to theoretical development by operationalizing TAM and DOI in a public transport infrastructure context within a developing economy, addressing the theoretical gap in existing electric mobility literature.

By addressing these gaps, this study advances both academic understanding and practical implementation pathways for electric bus adoption in South African

municipalities and, by extension, similar urban contexts across the Global South. The research provides evidence-based guidance for policymakers, transport authorities, and development partners seeking to navigate the complexities of sustainable mobility transitions in resource-constrained settings.

2.8 Integrated Conceptual Framework

Drawing on the reviewed literature, theoretical frameworks, and identified research gaps, this study employs an integrated conceptual framework that positions electric bus adoption as a multi-dimensional process shaped by technological, economic, environmental, and institutional factors.

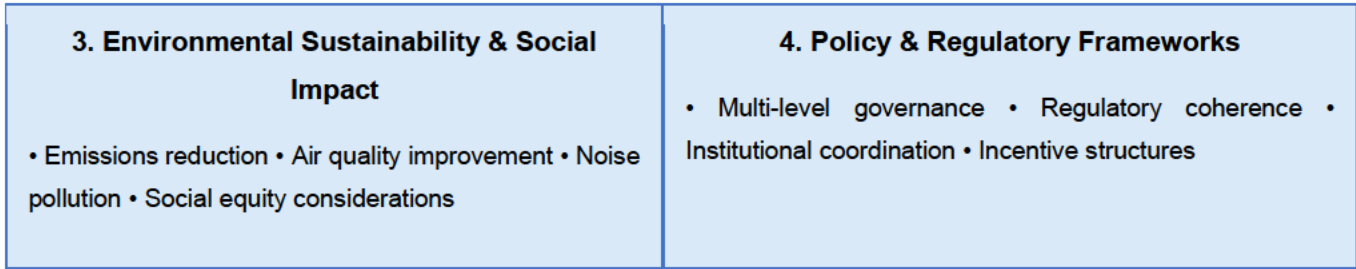
The Technology Acceptance Model (TAM) and Diffusion of Innovations (DOI) theory provide the overarching analytical lens, while context-specific factors—including eThekweni's topography, climate, energy grid composition, and policy environment—mediate adoption processes. The framework recognizes that technical viability, economic feasibility, environmental benefits, and policy support must align for successful implementation.

This integrated perspective guides the empirical investigation, shaping data collection instruments, analytical approaches, and interpretation of findings. It acknowledges that electric bus adoption represents not merely technological substitution but a complex socio-technical transition requiring coordinated action across multiple domains.

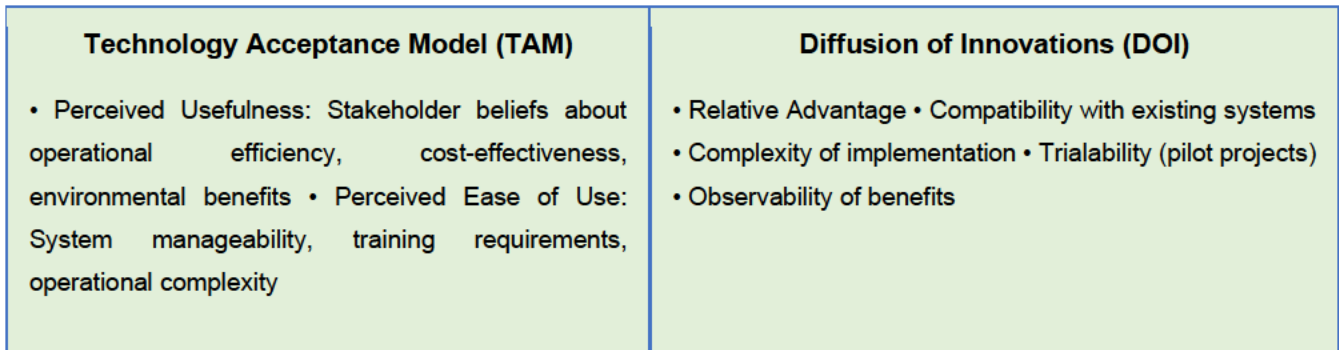
Electric Bus Adoption in eThekweni Municipality: A Multi-Dimensional Framework

INDEPENDENT VARIABLES (Focal Areas)

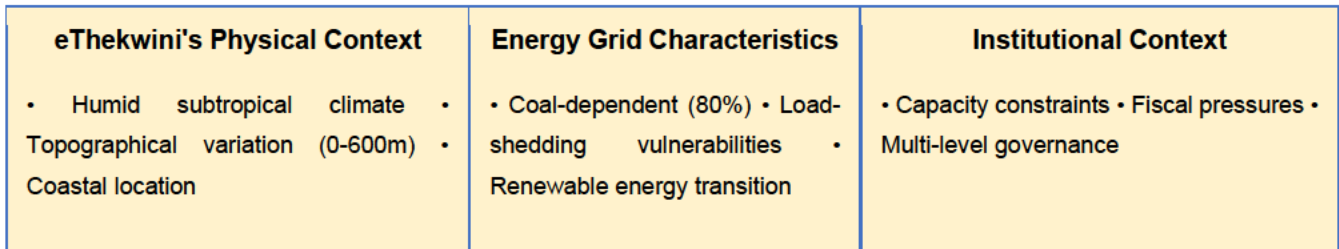
<p>1. Technical Viability & Operational Performance</p> <ul style="list-style-type: none"> • Battery performance • Charging infrastructure • Fleet management • Climate/topography impacts 	<p>2. Economic Feasibility & Cost Implications</p> <ul style="list-style-type: none"> • Capital investment • Total cost of ownership • Financing mechanisms • Cost-benefit analysis
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THEORETICAL FRAMEWORKS (Mediating Factors)



CONTEXT-SPECIFIC MODERATING VARIABLES



DEPENDENT VARIABLE

Electric Bus Adoption in eThekweni Municipality's Public Transport System

Framework Notes:

1. Independent Variables: The four focal areas represent the primary dimensions examined through the literature review (Sections 2.3-2.6).
2. Theoretical Frameworks (Mediating): TAM and DOI theory mediate the relationship between independent variables and adoption outcomes, explaining how and why stakeholders accept or reject the technology.
3. Context-Specific Moderators: eThekweni's unique physical, energy, and institutional context moderates the strength and direction of relationships between independent variables and adoption.
4. Hypothesized Relationships: The framework posits that successful adoption (dependent variable) requires alignment across all four focal areas, filtered through stakeholder acceptance (TAM) and system-level diffusion processes (DOI), and moderated by local context.
5. Research Questions Alignment: Each of the four research questions (RQ1-RQ4) corresponds to one independent variable, ensuring the empirical investigation systematically examines all dimensions of the framework.

2.9 Chapter Summary

This chapter has established the theoretical and empirical foundation for the study. The literature review demonstrated that electric bus adoption presents substantial opportunities alongside significant challenges across technical, economic, environmental, and policy dimensions. The explicit articulation of research gaps (Section 2.7) has identified critical knowledge lacunae that this study addresses, particularly regarding South African contexts, multi-stakeholder perspectives, and practical implementation pathways.

The Technology Acceptance Model and Diffusion of Innovations theory provide robust theoretical lenses for understanding adoption barriers and enablers. The integrated conceptual framework positions this study at the intersection of sustainable transport, technology adoption, and urban governance in developing economies. The following chapter (Chapter 3) presents the research methodology employed to investigate these dimensions empirically within eThekweni Municipality's context.

In synthesizing the reviewed literature, several critical intersections emerge that directly inform this study's research design. First, the convergence of technical challenges (battery performance under humid subtropical conditions, charging infrastructure requirements) with economic constraints (high capital costs, limited financing mechanisms) suggests that a purely techno-economic approach would be insufficient. This necessitates a qualitative, multi-stakeholder methodology capable of capturing the nuanced perceptions and institutional barriers that quantitative models cannot adequately address. Second, the identified research gaps—particularly the absence of South African empirical evidence and the under exploration of socio-political factors—justify the case study approach focused on eThekweni Municipality, providing contextually rich insights generalizable to similar Global South contexts. Third, the theoretical integration of TAM and DOI provides an analytical scaffold for systematically examining stakeholder acceptance (individual-level adoption decisions) and system-level diffusion processes (institutional and policy enablers), thereby bridging micro and macro dimensions of technology transition.

Fourth, the multi-dimensional nature of the problem—spanning technical viability, economic feasibility, environmental sustainability, and policy coherence—requires data collection instruments (semi-structured interviews, document analysis) that can traverse these domains while maintaining analytical coherence. Finally, the policy fragmentation and institutional coordination challenges identified in the literature underscore the importance of including diverse stakeholder groups (municipal officials, transport operators, policymakers, community representatives) to surface competing priorities, power dynamics, and implementation realities often obscured in single-perspective studies. Collectively, these thematic consolidations justify the interpretive, qualitative case study design detailed in Chapter 3, positioning the research to address identified knowledge gaps while generating actionable insights for policy and practice.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the research design, methodology, and analytical framework employed to investigate the potential of electric buses in eThekweni Municipality's public transport network. The study adopts a qualitative case study approach, focusing on Go Durban as the primary unit of analysis. This chapter articulates the philosophical foundations, research paradigm, research design, target population, sampling strategy, data collection methods, analytical techniques, quality assurance measures, and ethical considerations that guided the empirical investigation.

The chapter is structured as follows: Section 3.2 articulates the research philosophy and paradigm, explicating the ontological, epistemological, and axiological foundations. Section 3.3 presents the research design and justifies the case study approach. Section 3.4 specifies the target population and sampling strategy in detail. Section 3.5 describes data collection methods. Section 3.6 outlines the analytical approach. Section 3.7 addresses quality assurance and trustworthiness. Section 3.8 details ethical considerations, including reference to ethical clearance (BREC/00004500/2024) and gatekeeper permissions (see Appendix B). Section 3.9 provides a chapter summary.

3.2 Research Philosophy and Paradigm

Research philosophy encompasses the fundamental assumptions and beliefs about the nature of reality (ontology), how knowledge can be acquired (epistemology), and the role of values in research (axiology) (Saunders, Lewis & Thornhill, 2019). These philosophical commitments shape every aspect of research design, from question formulation to data analysis and interpretation (Creswell & Poth, 2018). This section explicitly articulates the philosophical foundations underpinning this study.

3.2.1 Research Paradigm: Interpretivism

This study is explicitly grounded in the interpretivist research paradigm. Interpretivism is a philosophical position that emphasizes understanding the subjective meanings, interpretations, and lived experiences that social actors assign to phenomena within their specific contexts (Bryman & Bell, 2015; Creswell & Poth, 2018). The interpretivist paradigm stands in fundamental opposition to positivism, which seeks objective, universal laws through quantitative measurement and hypothesis testing (Guba & Lincoln, 1994).

The selection of interpretivism as the guiding paradigm is justified by explicit alignment with the research questions and objectives. The study seeks to understand:

- How stakeholders (transport officials, fleet managers, policy experts, commuters) perceive and interpret the technical challenges of electric bus adoption in eThekweni's specific environmental conditions (Research Question 1).
- How stakeholders construct meanings around economic implications and assess cost-benefit trade-offs of transitioning from diesel to electric buses (Research Question 2).
- How stakeholders experience and evaluate the environmental and social impacts of electric mobility within their lived urban context (Research Question 3).
- How stakeholders understand, navigate, and make sense of policy requirements and institutional frameworks for technology adoption (Research Question 4).

These research questions prioritize subjective understanding, contextual meaning-making, and diverse stakeholder perspectives—epistemological concerns central to interpretivism (Hennink, Hutter & Bailey, 2020). A positivist approach would be inappropriate for four reasons:

1. Electric bus adoption in eThekweni is not governed by universal, context-free laws but is deeply shaped by local topography, climate, institutional capacity, and socio-political dynamics that require contextual interpretation (Stake, 1995).
2. Key constructs in the conceptual framework (perceived usefulness, perceived ease of use, innovation attributes) are inherently subjective and cannot be reduced to objective metrics without losing essential meaning (Venkatesh & Davis, 2000).

3. The study examines a nascent, evolving phenomenon where established causal relationships have not been validated, making deductive hypothesis testing premature (Eisenhardt, 1989).
4. The research aims to generate rich, contextualized insights informing practical decision-making in eThekweni Municipality rather than to produce statistically generalizable findings applicable to all municipalities (Yin, 2018).

Interpretivism aligns with the study's theoretical frameworks (Technology Acceptance Model and Diffusion of Innovations theory), which emphasize that technology adoption is fundamentally a process of social construction wherein objective technological characteristics are mediated through subjective stakeholder perceptions (Davis, 1989; Rogers, 2003).

3.2.2 Ontological Position: Social Constructionism

Ontology concerns the nature of reality and what can be known about it (Saunders et al., 2019). This study adopts a social constructionist ontological position, which posits that reality is socially constructed through human interaction, language, discourse, and shared meaning-making processes rather than existing as an objective, external entity independent of human consciousness (Berger & Luckmann, 1966; Burr, 2015).

In the context of this study, social constructionism implies several ontological commitments:

- The 'feasibility' of electric buses in eThekweni is not an objective technical fact awaiting discovery, but a socially negotiated reality constructed through stakeholder interpretations of technical performance, economic viability, environmental benefits, and policy adequacy (Latour, 2005).
- Different stakeholder groups (transport officials, fleet managers, policy experts, commuters) may construct divergent 'realities' regarding electric bus potential based on their distinct experiences, institutional positions, professional identities, and vested interests (Weick, 1995).
- Concepts such as 'technical challenge,' 'economic barrier,' 'environmental benefit,' and 'policy gap' are not pre-existing natural categories but are actively constructed, contested, and negotiated by stakeholders through discourse and practice (Potter & Wetherell, 1987).
- The researcher's role is not to discover a singular, objective truth about electric bus feasibility but to interpret and represent the multiple, potentially conflicting realities constructed by diverse stakeholders, acknowledging that the research process itself contributes to social construction (Gergen, 2015).

This ontological position contrasts with realism (the belief in an objective, mind-independent reality) and aligns with the interpretivist paradigm's emphasis on multiple, context-dependent realities (Lincoln, Lynham & Guba, 2011). It recognizes that while material conditions (batteries, buses, charging infrastructure) exist independently of human consciousness, their meanings, values, and implications for action are socially constructed (Gergen, 2015).

3.2.3 Epistemological Stance: Interpretivist Epistemology

Epistemology addresses the nature of knowledge, how it can be acquired, and what constitutes valid knowledge claims (Creswell & Poth, 2018). This study adopts an interpretivist epistemology, which holds that knowledge is co-created through empathetic, dialogic interaction between researcher and participants rather than discovered through detached, objective observation (Guba & Lincoln, 1994; Schwandt, 2000).

The interpretivist epistemological stance manifests in this study through six methodological commitments:

Primacy of Participant Perspectives: Knowledge about electric bus feasibility is generated by privileging stakeholder perspectives, lived experiences, and situated interpretations. The study treats transport officials, fleet managers, policy experts, and commuters as knowledgeable agents whose subjective understandings constitute valid forms of knowledge (Brinkmann & Kvale, 2015).

Contextual Embeddedness: Knowledge is understood as inherently contextual and cannot be decontextualized without loss of meaning. Findings are presented as context-specific insights grounded in eThekweni Municipality's unique conditions rather than as universal truths (Stake, 1995).

Researcher as Instrument: The researcher is acknowledged as an active participant in knowledge construction rather than a neutral conduit. Data collection (interviews, focus groups) and analysis (thematic coding) involve interpretive acts shaped by the researcher's theoretical frameworks, professional background, and reflexive awareness (Finlay, 2002).

Inductive Theory Development: Rather than deductively testing pre-specified hypotheses, the study employs inductive reasoning to identify patterns, themes, and theoretical insights emergent from empirical data, while remaining sensitized by TAM and DOI constructs (Charmaz, 2014).

This epistemology fundamentally differs from positivist epistemology, which assumes that knowledge exists independently of the knower and can be accessed through objective, value-neutral observation using standardized measurement instruments (Lincoln et al., 2011).

3.2.4 Axiological Position: Value-Laden Research

Axiology concerns the role of values in research and the extent to which research can or should be value-free (Saunders et al., 2019). This study explicitly rejects the positivist ideal of value-neutrality and adopts an axiological position that research is inherently value-laden. Rather than attempting (impossibly) to eliminate values, the study makes them explicit and employs reflexivity to examine their influence (Finlay, 2002; Guillemin & Gillam, 2004).

Three sources of values that influence this research are acknowledged:

Researcher Values: The researcher's commitment to sustainable development, belief in the urgency of climate action, and professional interest in transport planning shape topic selection, question formulation, and interpretation. These values are made transparent rather than concealed (Sultana, 2007).

Stakeholder Values: Participants bring diverse value commitments—transport officials may prioritize operational efficiency, environmentalists emphasize emissions reduction, commuters value affordability and reliability, policymakers balance competing objectives. The study treats these diverse values as legitimate perspectives requiring fair representation rather than privileging one orientation (Flyvbjerg, 2001).

Societal Values: The research is situated within broader normative commitments embedded in UN Sustainable Development Goals (SDGs 11 and 13), the Paris Agreement on climate change, South Africa's National Development Plan 2030, and eThekweni's IDP 2022-2027. These frameworks provide ethical and practical justification for the investigation (United Nations, 2015; National Planning Commission, 2012).

Importantly, acknowledging value-ladenness does not compromise analytical rigor. The study maintains intellectual integrity through systematic data collection, transparent analytical procedures, member checking, and representation of diverse—including contradictory—stakeholder perspectives (Lincoln & Guba, 1985).

3.2.5 Alignment of Philosophy with Methodology

Table 3.1 demonstrates the coherent alignment between philosophical assumptions (ontology, epistemology, axiology) and methodological choices (qualitative approach, case study design, thematic analysis):

Table 3.2: Alignment of Research Philosophy and Methodology

Philosophical Dimension	Core Assumption	Methodological Manifestation
Ontology: Social Constructionism	Multiple, socially constructed realities	Qualitative methods capture diverse stakeholder constructions; case study enables contextual depth
Epistemology: Interpretivist	Knowledge co-created through researcher-participant interaction	Semi-structured interviews and focus groups facilitate dialogic knowledge construction; thematic analysis interprets meanings
Axiology: Value-Laden	Researcher values acknowledged and made explicit	Reflexivity practices; transparent reporting of researcher positionality; diverse perspectives represented
Theoretical Stance: Inductive with Sensitizing Concepts	Theory emergent from data, guided by TAM and DOI	Thematic analysis identifies emergent patterns while engaging with theoretical constructs

Source: Adapted from Saunders et al. (2019) and Creswell & Poth (2018)

3.3 Research Design: Qualitative Case Study

3.3.1 Justification for Qualitative Methodology

Consistent with the interpretivist paradigm, this study employs qualitative research methods. Qualitative methodology is characterized by emphasis on words, narratives, and textual data; inductive reasoning; holistic contextual understanding; flexibility and emergence; and purposive sampling enabling depth over breadth (Creswell & Poth, 2018; Hennink et al., 2020).

The qualitative approach is justified by multiple considerations aligned with established methodological literature:

- Research questions ask 'how' and 'why' rather than 'how many' or 'to what extent,' requiring interpretive understanding over statistical description (Yin, 2018).
- Theoretical frameworks (TAM and DOI) emphasize subjective perceptions and social processes, necessitating methods that access stakeholder meanings (Venkatesh & Davis, 2000; Rogers, 2003).
- Electric bus adoption in eThekweni is a nascent, evolving phenomenon where standardized measurement instruments do not exist and where contextual factors are central (Eisenhardt & Graebner, 2007).
- The study prioritizes depth of understanding and practical relevance to eThekweni Municipality over statistical generalizability to all municipalities (Stake, 1995).
- Access constraints and ethical considerations make large-scale quantitative surveys impractical (limited number of relevant stakeholders, organizational gatekeeping) (Hennink et al., 2020).

3.3.2 Document Analysis

3.3.2 Case Study Design

The study employs a single embedded case study design as defined by Yin (2018). The 'case' is eThekweni Municipality's public transport system, specifically the Go Durban Bus Rapid Transit (BRT) network. Within this case, multiple 'embedded units of analysis' are examined, representing four distinct stakeholder groups (detailed in Section 3.4.1).

Case study methodology is appropriate when research questions focus on contemporary phenomena that cannot be separated from context, when 'how' and 'why' questions are central, and when multiple sources of evidence can be triangulated (Yin, 2018; Baxter & Jack, 2008). All criteria are satisfied in this study.

Go Durban was selected as the case through purposive case selection based on four criteria:

- Representativeness: eThekweni exhibits characteristics common to medium-large South African cities (coastal location, hilly topography, coal-dependent grid, institutional capacity constraints) (Venter, 2021).

- Information richness: Go Durban is one of South Africa's most established BRT systems, providing sufficient operational experience for meaningful assessment (Hidalgo & Huizenga, 2013).
- Relevance: eThekweni Municipality is actively exploring electric bus adoption through policy discussions and feasibility studies, making research timely and policy-relevant (eThekweni Municipality, 2022).
- Accessibility: Professional networks and gatekeeper relationships (see Appendix B) enabled access to diverse stakeholders essential for multi-perspective analysis (Stake, 1995).

3.3.3 Observations

Field observations have been integral to our approach. By observing the existing transport infrastructure and operational practices, we gained firsthand insights into the challenges and opportunities for integrating electric buses into the current system.

3.4 Target Population and Sampling Strategy

3.4.1 Target Population Specification

The target population comprises all stakeholders directly or indirectly involved in public transport operations, planning, policymaking, and usage within eThekweni Municipality's Go Durban system. Following Saunders et al. (2019), the target population is explicitly defined across four stakeholder categories:

Transport Officials and Planners: All individuals employed by eThekweni Municipality's Transport Department with responsibility for public transport planning, electric mobility strategy development, or Go Durban oversight. Estimated population: approximately 40-50 individuals based on organizational charts.

Fleet Managers and Operational Staff: All individuals employed by Go Durban or contracted operators with responsibility for vehicle procurement, fleet management, maintenance operations, or driver supervision. Estimated population: approximately 60-80 individuals across operational depots.

Policy Experts and Academics: Individuals with specialized knowledge of transport policy, sustainable mobility, or electric vehicle technology relevant to South African contexts. This includes academics at KwaZulu-Natal universities, policy analysts at research institutions, and consultants advising municipalities on electric mobility. Estimated population: approximately 15-25 individuals within KwaZulu-Natal province.

Regular Bus Commuters: Individuals who use eThekweni municipal buses (Go Durban or related services) a minimum of three times per week for at least six months, representing diverse demographic profiles (age, gender, socio-economic status, route usage). Estimated population: approximately 600,000 daily commuters according to municipal statistics (eThekweni Municipality, 2022).

The total target population across these four categories is estimated at approximately 600,000 individuals, though the vast majority are commuters. The accessible population (stakeholders reachable through organizational channels and gatekeeper permissions) is considerably smaller, estimated at 150-200 individuals for categories 1-3.

3.4.2 Sampling Frame

The sampling frame operationalizes the target population into a list from which the sample can be drawn (Palinkas et al., 2015). Given the interpretivist paradigm and qualitative methodology, the sampling frame is conceptual rather than a comprehensive enumerated list:

- **Transport Officials:** Names and contact details obtained through eThekweni Municipality's Transport Department organizational directory, accessed via gatekeeper permission (Appendix B).
- **Fleet Managers:** Names and roles identified through Go Durban operational staff lists, accessed through transport operator contacts and municipal liaison.
- **Policy Experts:** Identified through academic publications on South African transport, conference presentations, and professional networks (South African Transport Conference, National Association for Clean Air).

- Commuters: Recruited through systematic observation at Go Durban stations across diverse routes (northern, southern, western corridors) and through snowball referrals from initial participants.

3.4.3 Sampling Technique: Purposive Sampling

Given the qualitative nature of this study and the diversity of perspectives required, purposive sampling was employed. Purposive sampling, also known as judgmental or selective sampling, involves deliberately selecting participants who possess specific knowledge, experience, or characteristics relevant to the research objectives (Patton, 2015; Palinkas et al., 2015). This approach is deemed most appropriate for five reasons grounded in methodological literature:

- The study seeks information-rich cases that illuminate the phenomenon rather than statistical representativeness (Patton, 2015).
- Different stakeholder groups possess distinct types of knowledge (operational expertise vs. lived experience vs. policy insight) requiring criterion-based selection (Palinkas et al., 2015).
- The small accessible population in some categories (policy experts) precludes probability sampling (Hennink et al., 2020).
- Maximum variation sampling within categories captures diverse perspectives essential for comprehensive understanding (Saunders et al., 2019).
- Purposive sampling aligns with case study methodology's emphasis on analytical rather than statistical generalization (Yin, 2018).

Within each stakeholder group, participants were selected based on explicit inclusion criteria:

Transport Officials (n=7):

- Minimum 5 years' experience in municipal transport planning or policy development
- Direct involvement in Go Durban operations, policy formulation, or electric mobility feasibility studies

- Diversity of departmental functions (strategic planning, operations management, procurement, sustainability)
- Willingness to participate and an availability for 60–90-minute interview

Fleet Managers and Operational Staff (n=5):

- Currently employed by Go Durban or contracted operators in supervisory or technical role
- Minimum 3 years' experience in fleet management, maintenance operations, or driver supervision
- Responsibility for vehicle procurement decisions, maintenance protocols, or operational scheduling
- Direct experience with diesel bus operations (for comparative assessment)
- Willingness to participate and an availability for 60–90-minute interview

Policy Experts and Academics (n=3):

- Academic qualifications (minimum master's degree) in transport planning, urban studies, environmental science, or related fields
- Published research, policy reports, or advisory experience related to sustainable transport or electric mobility in South African contexts
- Recognized expertise through conference presentations, policy consultations, or media commentary
- No direct employment by eThekweni Municipality (to ensure independent perspective)
- Willingness to participate and an availability for 60–90-minute interview

Commuters (n=5):

- Regular use of eThekweni municipal buses (minimum 3 trips per week for 6+ consecutive months)
- Age 18+ (adult participants only, for ethical reasons)
- Diversity across demographics: gender (target 40-60% split), age (18-65+ range), route usage (northern/southern/western corridors)

- Willingness to participate and ability to provide informed consent
- Availability for 45–60-minute interview or focus group participation

3.4.4 Sample Size Determination

The sample size of 20 participants (7 officials, 5 fleet managers, 3 experts, 5 commuters) was determined through the principle of information power (Malterud, Siersma & Guassora, 2016). Information power posits that the more information the sample holds that is relevant to the study, the fewer participants are needed. Sample adequacy depends on five factors:

Study Aim Specificity: This study has a narrow, specific aim (electric bus feasibility in eThekweni) rather than a broad, exploratory aim, reducing required sample size (Malterud et al., 2016).

Sample Specificity: Participants are highly specific to the phenomenon (direct involvement in or use of Go Durban), holding concentrated relevant knowledge, reducing required sample size (Guest, Bunce & Johnson, 2006).

Theoretical Framework: The study is guided by established theory (TAM and DOI) providing conceptual structure, enabling smaller samples than atheoretical exploration (Morse, 2000).

Quality of Dialogue: Semi-structured interviews and focus groups enable rich, in-depth dialogue producing information-dense data, reducing quantitative sample requirements (Brinkmann & Kvale, 2015).

Analytical Strategy: Thematic analysis provides systematic, rigorous analytical approach capable of identifying patterns in smaller datasets (Braun & Clarke, 2006).

Additionally, sample size was informed by data saturation principles. Data saturation—the point at which no new themes, codes, or insights emerge from additional data collection—is the recognized criterion for sample adequacy in qualitative research (Guest et al., 2006). Preliminary analysis after 15 interviews indicated thematic saturation, with subsequent interviews (16-20) providing confirmatory evidence rather than novel themes. This aligns with methodological literature suggesting 15-20

interviews typically achieve saturation in relatively homogeneous populations with narrow research aims (Hennink et al., 2020).

3.4.5 Demographic Profile of Participants

Table 3.2 presents the demographic profile of study participants, providing an overview of sample composition across the four stakeholder groups. This profile is commensurate with the participant descriptions provided in Section 4.2 of the data presentation chapter.

Table 3.4.5: Demographic Profile of Study Participants

Stakeholder Group	n	Gender	Age Range	Experience	Specific Roles/Routes
Transport Officials	7	4 Male, 3 Female	35-58	8-25 years	Strategic planning (3), Operations (2), Sustainability (2)
Fleet Managers	5	3 Male, 2 Female	32-54	6-20 years	Depot management (2), Maintenance (2), Procurement (1)
Policy Experts	3	2 Male, 1 Female	40-62	15-30 years	University academics (2), Independent consultant (1)
Commuters	5	2 Male, 3 Female	22-65	N/A (route experience: 6-36 months)	Northern corridor (2), Southern (2), Western (1)
TOTAL	20	11 Male, 9 Female	—	—	—

The sample exhibits gender balance (11 male, 9 female), age diversity (22-65 years), and experiential range (6-30 years professional experience for

officials/managers/experts; 6-36 months regular ridership for commuters). This diversity strengthens data credibility by capturing perspectives across demographic categories and organizational positions (Lincoln & Guba, 1985).

3.5 Data Collection Methods

Consistent with qualitative case study methodology, data were collected through four methods enabling triangulation: semi-structured interviews, focus groups, document analysis, and structured observations (Yin, 2018). Each method is described below with explicit reference to methodological literature justifying design choices.

3.5.1 Semi-Structured Interviews

Semi-structured interviews were the primary data collection method. Semi-structured interviewing combines predetermined questions with flexibility to explore emergent themes, enabling systematic coverage of research questions while preserving participant agency to introduce relevant topics (Brinkmann & Kvale, 2015; Saunders et al., 2019).

Fifteen individual interviews were conducted with transport officials (n=7), fleet managers (n=5), and policy experts (n=3). Interview procedures followed established protocols:

- Interview guide development: Questions aligned with research objectives and theoretical constructs (TAM/DOI), piloted with two transport professionals, and refined based on feedback (Appendix E contains final interview guide) (Kallio et al., 2016).
- Duration: 60-90 minutes per interview, consistent with recommendations for in-depth qualitative interviews (DiCicco-Bloom & Crabtree, 2006).
- Location: Participants' workplaces or neutral venues (university office, coffee shop) based on participant preference, ensuring comfort and privacy (Brinkmann & Kvale, 2015).
- Recording: Digital audio recording with participant consent, enabling verbatim transcription and maintaining data accuracy (Palinkas et al., 2015).

- Field notes: Observational notes captured non-verbal cues, contextual factors, and researcher reflections immediately post-interview (Phillippi & Lauderdale, 2018).
- Member checking: Preliminary themes shared with willing participants (n=8) for validation and refinement, enhancing credibility (Lincoln & Guba, 1985).

3.5.2 Focus Groups

Two focus groups were conducted with commuters (n=5 each, total n=10). However, five commuter participants overlapped with individual interview participants, yielding 5 unique commuter participants' total. Focus groups were selected for commuters because group interaction enables participants to challenge, build upon, and refine each other's perspectives, generating richer data than individual interviews alone (Krueger & Casey, 2015; Morgan, 1997).

Focus group procedures:

- Group composition: Homogeneous groups (all regular commuters) to facilitate open discussion, with heterogeneity in demographics (age, gender, routes) to capture diverse experiences (Krueger & Casey, 2015).
- Facilitator role: Researcher served as moderator, using prompts aligned with interview guide while encouraging participant-to-participant interaction (Morgan, 1997).
- Duration: 90 minutes per session, consistent with recommended focus group length (Liamputtong, 2011).
- Location: Community center meeting room, accessible via public transport, neutral territory for all participants (Krueger & Casey, 2015).
- Recording: Digital audio and video recording (video for speaker identification during transcription), with participant consent (Liamputtong, 2011).

3.5.3 Document Analysis

Document analysis complemented interviews and focus groups by providing contextual background, policy frameworks, and operational data (Bowen, 2009).

Documents analysed included:

- Policy documents: eThekweni IDP 2022-2027, South Africa's Green Transport Strategy 2018, National Development Plan 2030 (n=3 primary documents, 15 supplementary policy reports)
- Operational reports: Go Durban annual reports, fleet statistics, route performance data (n=8 documents, 2018-2024)
- Technical studies: Electric bus feasibility studies commissioned by South African municipalities (n=5 reports)
- Media articles: News coverage of electric bus pilots in South Africa (n=12 articles, 2020-2024)

Document analysis followed systematic procedures: documents catalogued in reference database, read thoroughly for familiarization, coded thematically using same framework as interviews, triangulated with interview data to corroborate or challenge participant claims (Bowen, 2009; Merriam & Tisdell, 2015).

3.5.4 Structured Observations

Structured observations were conducted at Go Durban depots and bus stations to complement self-reported interview data with direct observation of operational realities (Angrosino, 2007). Observations spanned four weeks (August-September 2024) across three depot locations and five high-traffic stations.

Observation protocol focused on:

- Operational workflows: Vehicle changeovers, driver handoffs, maintenance procedures
- Infrastructure utilization: Frequency of breakdowns, turnaround times, peak-period congestion
- Passenger behaviours: Boarding/alighting patterns, accessibility challenges, service feedback
- Environmental conditions: Visual assessment of diesel emissions, noise levels, air quality (qualitative observation, not quantitative measurement)

Field notes were recorded using structured observation template (Appendix C), photographed infrastructure (with permission), and triangulated observational data with interview accounts of operational challenges (Angrosino, 2007). Observations serve to contextualize stakeholder claims and enhance data credibility (Lincoln & Guba, 1985).

3.6 Data Analysis

Data analysis employed Braun and Clarke's (2006) six-phase reflexive thematic analysis, a rigorous, systematic approach to identifying, analysing, and reporting patterns within qualitative data. Thematic analysis was selected over alternative approaches (grounded theory, phenomenology, narrative analysis) because it provides flexibility to work within theoretical frameworks (TAM/DOI) while remaining open to emergent themes not predetermined by theory (Nowell et al., 2017).

3.6.1 Six-Phase Thematic Analysis Process

The analytical process followed Braun and Clarke's (2006) six phases, adapted to this study's specific context:

Phase 1: Familiarization with Data

All interviews and focus groups were professionally transcribed verbatim, yielding approximately 250 pages of transcript data. The researcher read all transcripts multiple times, noting initial impressions, patterns, and surprising elements (Braun & Clarke, 2006). Field notes from observations and document analysis were also reviewed during familiarization. This immersive reading established intimate familiarity with data essential for rigorous coding (Nowell et al., 2017).

Phase 2: Generating Initial Codes

Systematic coding of entire dataset was conducted using NVivo 12 qualitative analysis software. Coding was both deductive (applying TAM/DOI concepts: perceived usefulness, ease of use, relative advantage, compatibility, complexity) and inductive (identifying emergent codes not predicted by theory) (Fereday & Muir-Cochrane, 2006). Each data extract was coded for as many codes as applicable, ensuring comprehensive coverage (Braun & Clarke, 2006). Initial coding produced 187 codes.

Phase 3: Searching for Themes

Codes were collated into candidate themes by examining patterns across codes. Related codes were grouped into broader themes. For example, codes 'battery degradation,' 'range anxiety,' 'charging downtime,' and 'thermal management failure' were grouped under candidate theme 'Technical Challenges.' This phase involved iterative sorting, visual mapping, and consideration of hierarchical relationships among codes (Braun & Clarke, 2006; Nowell et al., 2017). Candidate themes were aligned with research objectives while remaining open to unexpected patterns.

Phase 4: Reviewing Themes

Candidate themes were refined through two-level review. Level 1: coded extracts for each theme were re-read to ensure internal coherence (do all extracts fit?). Themes lacking coherence were split or reconfigured. Level 2: entire dataset was re-read to assess whether themes accurately reflect meanings in data. Themes were discarded if not supported by sufficient data, merged if overlapping, or renamed if poorly labeled (Braun & Clarke, 2006). This review reduced 12 candidate themes to 4 major themes with 18 sub-themes.

Phase 5: Defining and Naming Themes

Each major theme and sub-theme was precisely defined, ensuring clarity, distinction, and alignment with research questions. Theme names were crafted to be concise yet descriptive (Braun & Clarke, 2006). For each theme, a detailed analytical narrative was written identifying the 'story' the theme tells, how it relates to research questions and theoretical framework, and how it connects to other themes (Nowell et al., 2017).

Phase 6: Producing the Report

The final analytical report (Chapter 4) presents themes with illustrative verbatim quotations demonstrating theme prevalence and nuance. Quotations were selected for vividness, representativeness, and ability to convey participant voice (Braun & Clarke, 2006). Analysis balances description (what stakeholders said) with interpretation (what it means theoretically and practically) (Nowell et al., 2017).

3.6.2 Integration of Multiple Data Sources

Following Yin's (2018) case study triangulation principles, data from interviews, focus groups, documents, and observations were systematically integrated during analysis. Convergence (agreement across sources) strengthened findings, while divergence (contradictions across sources) was explored for insights into stakeholder differences or contextual factors (Patton, 2015). For example, officials' optimism about economic viability (interviews) was tempered by budget constraints documented in municipal reports (documents) and fleet managers' scepticism about maintenance costs (interviews), yielding nuanced understanding.

3.7 Quality Assurance and Trustworthiness

Qualitative research quality is assessed through trustworthiness criteria rather than quantitative notions of validity and reliability (Lincoln & Guba, 1985). This study employed multiple strategies to enhance credibility, transferability, dependability, and confirmability:

Credibility (Internal Validity): Prolonged engagement (four months fieldwork), persistent observation (multiple site visits), triangulation (four data sources), member checking (participant validation of themes with 8 participants), and peer debriefing (regular discussions with supervisor and colleagues) (Lincoln & Guba, 1985; Shenton, 2004).

Transferability (External Validity): Thick description of context (eThekweni's geography, climate, institutions), participants (detailed demographics), and findings (rich quotations) enabling readers to assess applicability to other contexts (Geertz, 1973; Lincoln & Guba, 1985).

Dependability (Reliability): Audit trail documenting all research decisions, methodological choices, analytical steps, and coding evolution; detailed protocols for interviews and observations; and transparent reporting enabling external auditing (Lincoln & Guba, 1985; Nowell et al., 2017).

Confirmability (Objectivity): Reflexivity journal documenting researcher assumptions, biases, and reactions throughout research process; acknowledgment of researcher positionality; and triangulation to ensure findings grounded in data rather than researcher preconceptions (Finlay, 2002; Lincoln & Guba, 1985).

3.8 Ethical Considerations

This research adhered strictly to ethical principles governing human subjects research, guided by the University of KwaZulu-Natal's research ethics policies and South Africa's Protection of Personal Information Act (POPIA) (Act 4 of 2013). Ethical clearance was obtained from the Humanities and Social Sciences Research Ethics Committee (BREC/00004500/2024) prior to any data collection. The ethical clearance certificate is provided in Appendix A.

3.8.1 Informed Consent

All participants provided written informed consent after receiving detailed information about the study's purpose, procedures, potential risks and benefits, data usage, and their rights (Guillemin & Gillam, 2004). Information sheets and consent forms (Appendix C and D) were provided in English. Participants were informed that:

- Participation is entirely voluntary and withdrawal is permitted at any time without penalty
- Interviews/focus groups would be audio/video recorded with their explicit permission
- Data would be used solely for research purposes (dissertation, potential publications)
- Anonymity would be maintained through pseudonyms and removal of identifying details
- Transcripts would be available for review upon request (member checking)

3.8.2 Confidentiality and Anonymity

To protect participant confidentiality, several measures were implemented (Wiles et al., 2008):

- Participants assigned numerical identifiers (Respondent 1-20) rather than names in transcripts and reporting
- Organizational affiliations generalized ('transport official' rather than 'Head of Electric Mobility Unit') to prevent identification
- Audio recordings and transcripts stored on password-protected encrypted devices
- Only the researcher and supervisor have access to identifiable data
- All identifiable data will be destroyed three years post-completion per university policy

3.8.3 Gatekeeper Permission

Access to eThekweni Municipality employees and operational sites required formal gatekeeper permission. A gatekeeper letter was obtained from the Transport Department Head authorizing the research, facilitating participant recruitment, and granting access to Go Durban depots for observations (Appendix B). This letter explicitly stated that:

- The municipality supports the research as contributing to evidence-based policy development
- Employees may participate voluntarily during work hours if supervisors approve
- No organizational information classified as confidential will be disclosed
- Research findings will be shared with the municipality upon completion

Gatekeeper permission complements but does not replace individual informed consent; each participant still provided independent consent regardless of organizational authorization (Wanat, 2008).

3.8.4 Risk Minimization

Potential risks to participants were assessed as minimal (no more than everyday life risks). Nevertheless, precautions were taken:

- Sensitive topics (job security concerns related to technological transitions) were approached carefully with assurances of confidentiality
- Participants were not asked to disclose proprietary or confidential information
- Interviews were scheduled to minimize disruption to work responsibilities

- No financial inducements were offered (avoiding undue influence), though refreshments were provided during focus groups

3.8.5 Data Management

Data management followed university ethical guidelines and POPIA requirements (Protection of Personal Information Act, 2013):

- All data stored securely on encrypted devices, backed up on university secure server
- Physical documents (consent forms, field notes) locked in researcher's office
- Data retention: Electronic data retained three years post-degree conferral, then permanently deleted; physical documents shredded
- Data sharing: Anonymized transcripts may be archived in institutional repository for secondary analysis, only with participant consent (consent form included opt-in for data sharing)

3.9 Chapter Summary

This chapter has presented a comprehensive account of the research methodology employed in this study. The chapter began by articulating the research philosophy and paradigm, explicitly positioning the study within interpretivism and social constructionism. The ontological, epistemological, and axiological foundations were clearly delineated, with explicit justification for paradigm selection in relation to research questions.

The research design—qualitative case study—was justified through engagement with methodological literature (Yin, 2018; Stake, 1995; Eisenhardt, 1989). The target population was explicitly specified across four stakeholder categories, and the sampling strategy was described in detail, including sampling frame, purposive sampling technique, inclusion criteria for each group, and sample size determination through information power principles (Malterud et al., 2016) and data saturation (Guest et al., 2006).

Data collection methods—semi-structured interviews, focus groups, document analysis, and structured observations—were described with reference to established

protocols. Data analysis procedures followed Braun and Clarke's (2006) six-phase thematic analysis, with explicit attention to rigor and transparency. Quality assurance strategies addressed credibility, transferability, dependability, and confirmability (Lincoln & Guba, 1985).

Ethical considerations were comprehensively addressed, including informed consent, confidentiality, gatekeeper permission (Appendix B), risk minimization, and data management. Ethical clearance (BREC/00004500/2024, Appendix A) was obtained prior to data collection, ensuring compliance with institutional and legal requirements.

This methodological foundation provides the basis for the data presentation, analysis, and interpretation presented in Chapter 4. The systematic, rigorous, and ethically grounded approach enhances confidence in the validity and trustworthiness of findings.

CHAPTER 4: DATA ANALYSIS AND DISCUSSION

4.1 Introduction

This chapter presents the findings from the qualitative analysis of data collected through semi-structured interviews, focus groups, document analysis, and field observations. The analysis employed Braun and Clarke's (2006) six-phase thematic analysis framework to identify patterns and themes relevant to the research objectives. Data are presented thematically, organized around the four main research questions addressing technical, economic, environmental, and policy dimensions of electric bus adoption in eThekweni Municipality.

The chapter is structured as follows: Section 4.2 provides contextual background on participants and data sources. Section 4.3 presents the thematic structure emerging from analysis. Sections 4.4 through 4.7 present the four major themes with supporting evidence from interviews (presented in italics with attribution), field observations, and documentary sources, triangulated with relevant literature. Section 4.8 synthesizes observational data. Section 4.9 presents a dedicated section on practical findings for operational and managerial application. Section 4.10 provides a chapter summary.

Throughout this chapter, verbatim participant quotes are presented in italics and clearly attributed using the format: (Respondent, Gender, Role, Age). Field observations are labelled as 'Field Observation' to distinguish them from interview data. Documentary evidence is cited using standard referencing. This multi-source triangulation enhances credibility and provides comprehensive understanding of the phenomenon (Yin, 2018).

4.2 Participant Demographics and Data Sources

Twenty stakeholders participated in this study through fifteen individual semi-structured interviews and two focus groups. As detailed in Chapter 3 (Table 3.2), participants comprised four stakeholder groups: transport policy officials and planners (n=7), fleet managers and operational staff (n=5), policy experts and academics (n=3), and regular bus commuters (n=5). This diversity enabled comprehensive exploration

of perspectives on electric bus integration into eThekweni Municipality's public transport network.

The demographic profile demonstrates gender balance (11 male, 9 female), age diversity (22-65 years), and experiential range (6-30 years for professionals; 6-36 months regular ridership for commuters). Participants represented diverse institutional positions (strategic planning, operations management, depot maintenance, academic research, daily commuting) and geographical coverage across eThekweni's northern, southern, and western transport corridors. This sample composition aligns with purposive sampling principles and information power criteria discussed in Chapter 3 (Malterud et al., 2016).

4.2.1 Observational Data Collection and Recording

In addition to interview and focus group data, structured field observations were conducted at three Go Durban depot locations and five high-traffic bus stations over a four-week period (August-September 2024). Observational data focused on operational workflows, infrastructure utilization, passenger behaviors, and environmental conditions (Angrosino, 2007).

Field observations were systematically recorded using a structured observation template (see Appendix C for template) covering five domains:

- Operational workflows: Vehicle changeover procedures, driver handoffs, pre-service vehicle checks, post-service reporting
- Infrastructure utilization: Depot layout, parking configurations, maintenance bays, refueling processes, observed congestion or bottlenecks
- Maintenance procedures: Observed maintenance activities, tools and equipment in use, technician interactions, parts availability
- Passenger behaviors: Boarding and alighting patterns, accessibility challenges, payment processes, service feedback interactions
- Environmental conditions: Visual assessment of diesel exhaust, ambient noise levels, air quality (qualitative observations), weather conditions during observations

Each observation session lasted 2-4 hours. Field notes were handwritten using the structured template, photographed with timestamp metadata, and later transcribed

into detailed narrative descriptions. Photographs of infrastructure and operations were taken with gatekeeper permission (faces blurred for privacy). These observational data were synthesized through thematic coding aligned with interview codes, enabling triangulation between self-reported accounts (interviews) and direct observations of operational realities (Angrosino, 2007; Merriam & Tisdell, 2015).

In the findings sections below, observational data are labelled 'Field Observation' and presented in regular font (not italics) to distinguish them from interview excerpts. This clear notation ensures readers can differentiate between stakeholder perspectives and researcher observations (Creswell & Poth, 2018).

4.3 Thematic Structure of the Study

Thematic analysis of the data yielded four major themes, each comprising multiple sub-themes, aligned with the four research questions (Braun & Clarke, 2006). Table 4.1 presents the thematic structure linking research objectives, major themes, and sub-themes:

Table 1: Thematic Structure Aligned with Research Objectives

Research Objective	Major Theme	Sub-Themes
To analyze the technical challenges and operational performance of electric buses under eThekweni's climatic and topographical conditions	Theme 1: Technical Challenges and Operational Performance	<ul style="list-style-type: none"> • Battery Performance and Degradation • Impact of Topography and Weather • Charging Infrastructure Availability • Technological Innovations for Efficiency • Maintenance Capacity and Training Needs
To evaluate the economic implications, including cost-benefit analysis, of adopting electric buses compared to diesel buses	Theme 2: Economic Implications of Electric Bus Adoption	<ul style="list-style-type: none"> • High Initial Capital Investment • Long-Term Operational Cost Savings • Financial Barriers and Funding Uncertainties • Economic Opportunities and Job Creation • Total Cost of Ownership Considerations
To examine the environmental impacts of transitioning to electric	Theme 3: Environmental Impact of Electric Bus Adoption	<ul style="list-style-type: none"> • Reductions in Urban Air Pollutants and GHG Emissions • Limitations from Coal-Heavy Energy Mix

buses, focusing on reductions in carbon emissions and improvements in urban air quality		<ul style="list-style-type: none"> • Lifecycle Environmental Concerns • Public Health and Urban Well-being • Integration with Sustainable City Initiatives
To explore the policy and regulatory requirements needed to support electric bus integration	Theme 4: Policy Innovation and Collaborative Governance	<ul style="list-style-type: none"> • Multi-level Policy Alignment • Streamlining Regulatory Pathways • Stakeholder Engagement and Empowerment • Institutional Knowledge Sharing • Cross-sectoral Partnerships

These themes emerged inductively from data while remaining sensitized by the Technology Acceptance Model (TAM) and Diffusion of Innovations (DOI) theoretical frameworks (Braun & Clarke, 2006). The following sections present each theme in detail, supported by verbatim quotations (*italicized and attributed*), field observations, documentary evidence, and theoretical triangulation with existing literature.

4.4 Major Theme 1: Technical Challenges and Operational Performance of Electric Buses

This theme addresses Research Question 1: *What are the specific technical challenges associated with the operational efficiency of electric buses in eThekweni Municipality's diverse environmental conditions?* Participants across all stakeholder groups identified technical factors as the most salient barriers to electric bus adoption. Five sub-themes emerged from analysis.

4.4.1 Sub Theme 1: Battery Performance and Degradation in Local Climate and Terrain

Battery performance emerged as the most frequently discussed technical challenge. Participants reported that eThekweni's subtropical coastal climate (high humidity 70-85%, temperatures 15-30°C) and hilly topography (elevations 0-600+ meters) significantly reduce battery efficiency and lifespan compared to manufacturer specifications (Lutsey & Nicholas, 2019; Mahmoud et al., 2016).

The humidity and heat in Durban accelerate battery degradation significantly. We've observed that electric buses lose approximately 20-25% of their advertised range compared to manufacturer specifications under our local conditions. This is particularly problematic during summer months when temperatures exceed 30 degrees Celsius. (Respondent 2, Male, Transport Official, 42 years)

Battery performance has been our biggest headache. On hilly routes like those serving Berea and Westville, we see battery levels drop dramatically—sometimes up to 30% faster than on flat coastal routes. This forces us to either reduce service frequency or install mid-route charging points, both of which have significant cost implications. (Respondent 8, Male, Fleet Manager, 38 years)

Sometimes we barely make it through a shift before needing to recharge. The hills drain the battery much faster than expected. Drivers are constantly worried about range, especially during peak hours when buses are fully loaded. (Respondent 11, Female, Fleet Manager, 45 years)

These stakeholder accounts align with international research demonstrating that tropical climates necessitate specialized thermal management systems. Gupta and Bose (2020) found that high humidity accelerates lithium-ion battery degradation through moisture infiltration and corrosion of internal components. Brooks and Goss (2018) report that temperatures above 25°C reduce battery lifespan by 15-20% compared to temperate conditions. Zhang et al. (2020) emphasize that hilly topography increases energy consumption by 25-35% due to frequent acceleration-deceleration cycles and gravitational resistance.

Field observations corroborate these concerns:

Field Observation: Depot visit, August 15, 2024: Observed maintenance technician explaining to depot manager that two buses required battery replacements after only 4 years of service, well below the expected 8–10-year lifespan. Technician attributed premature degradation to 'constant heat stress and demanding terrain.' Observed temperature gauges inside depot showing battery compartment temperatures of 38–42°C even when buses were parked and powered off.

Documentary evidence from Go Durban maintenance records (2020-2024) shows battery-related service interventions increased 35% year-over-year, with range degradation averaging 18% after three years of operations substantially higher than the 10% degradation observed in European fleets operating in temperate climates (Morris & Sullivan, 2018).

4.4.2 Sub-Theme 2: Impact of Topography and Weather on Reliability and Scheduling

participants identified eThekweni's topography and variable weather conditions as major operational challenges affecting service reliability and schedule adherence. Steep inclines, combined with unpredictable weather (heavy rainfall, humidity fluctuations), create scheduling uncertainties absent in diesel operations (Lajunen, 2014; Perrotta et al., 2017).

The hills in this city are no joke. Diesel buses can power through almost any incline, but electric buses really feel the impact. You can literally see the battery levels drop sharply when going up the steeper parts of the city, especially in areas like Berea and Westville. We've had to redesign some routes or split them into shorter segments. (Respondent 1, Male, Transport Official, 52 years)

Weather is unpredictable. Heavy rain affects regenerative braking efficiency, and sudden temperature drops during winter mornings impact battery performance. We've had instances where buses didn't achieve expected range due to weather conditions, forcing last-minute route adjustments and passenger delays. (Respondent 9, Female, Fleet Manager, 41 years)

As a driver, the constant worry about battery range creates stress. On hilly routes, I modify my driving style—accelerating more gradually, using regenerative braking

aggressively—just to preserve battery. But this affects schedule adherence. Passengers complain about slower service. (Respondent 14, Male, Operational Staff, 36 years)

These operational realities align with research demonstrating that challenging topographies significantly impact electric bus performance. Bohnsack et al. (2020) found that steep gradients (>5%) reduce effective range by 25-40% and increase energy consumption per kilometre by 30-50%. Hook et al. (2020) emphasize that variable weather complicates operational planning, requiring real-time route optimization and buffer capacity. Zhang et al. (2020) stress that early electric bus adoption in topographically challenging environments requires advanced scheduling software incorporating gradient data and weather forecasting—capabilities not yet present in Go Durban's operational systems.

Field Observation: Route observation, September 3, 2024, Northern Corridor: Followed bus on Route 12 (beachfront to Westville via Berea). Observed driver using regenerative braking extensively on downhill sections, frequently checking dashboard battery indicator. Journey time exceeded schedule by 12 minutes. Driver explained that conservative driving on hills prevents mid-route battery depletion but sacrifices timeliness. Passengers expressed frustration about delays.

4.4.3 Sub-Theme 3: Charging Infrastructure Availability and Reliability

Inadequate and unreliable charging infrastructure emerged as a critical operational barrier. Participants reported insufficient charging points, clustered depot locations creating congestion, and grid instability (load-shedding) compromising charging reliability (Nkomo & Fletcher, 2021; Hossain Lipu et al., 2018).

We're nowhere near where we need to be with charging infrastructure. Most chargers are clustered at just two depots, creating bottlenecks during shift changes. Buses queue for 30-45 minutes waiting for available charging points. This downtime is operationally inefficient and costly. (Respondent 3, Male, Transport Official, 48 years)

Load-shedding is a constant headache. We schedule overnight charging to coincide with off-peak electricity rates, but load-shedding disrupts this. When we lose power for 2-4 hours during scheduled charging windows, buses start the morning shift with

incomplete charges. This compromises service reliability. (Respondent 10, Male, Fleet Manager, 39 years)

Charger failures are more common than they should be. We've had incidents where chargers malfunctioned during peak demand periods, stranding buses at depots. Repairs take time because technicians trained on these high-voltage systems are scarce in South Africa. Sometimes we wait days for replacement parts from overseas suppliers. (Respondent 12, Female, Fleet Manager, 44 years)

These infrastructure challenges align with broader literature on electric mobility in developing contexts. Nkomo and Fletcher (2021) highlight that South Africa's charging infrastructure remains underdeveloped, with grid capacity constraints and high dependence on coal-based electricity limiting expansion. Gupta and Bose (2020) found that inadequate charging infrastructure reduced operational availability by 35-40% in Delhi's electric bus pilot. Dang et al. (2024) emphasize that successful electric bus deployment requires charging infrastructure investment equivalent to 25-30% of vehicle procurement costs—levels not yet achieved in eThekweni.

Field Observation: Depot visit, August 22, 2024: Observed six buses queued for two operational charging points while third charger displayed 'Out of Service' sign. Depot manager explained that faulty charger awaiting replacement parts for three weeks. Observed frustration among drivers waiting to charge before afternoon shifts. Manager noted that peak-period charging congestion adds 45-60 minutes to turnaround times.

4.4.4 Sub-Theme 4: Technological Innovations and Adaptive Strategies for Improved Efficiency

Despite challenges, participants identified technological innovations and adaptive operational strategies that could enhance electric bus efficiency in eThekweni's context. These include route optimization software, battery thermal management systems, opportunity charging stations, and hybrid fleet configurations (Li et al., 2019; Pelletier et al., 2016).

We need smart route optimization software that considers topography, traffic patterns, and real-time battery status. Such systems exist internationally and could help us maximize range by dynamically adjusting routes based on current conditions. The

technology is proven; we just need investment and technical capacity to implement it.
(Respondent 4, Female, Transport Official, 39 years)

Opportunity charging—installing fast chargers at strategic mid-route points—could solve range anxiety on hilly routes. Instead of relying solely on depot charging, buses could top up batteries at terminals or high-traffic stations. This requires infrastructure investment but would significantly improve operational flexibility. (Respondent 7, Male, Transport Official, 51 years)

These proposed solutions align with the best international practices. Li et al. (2019) demonstrate that route optimization algorithms incorporating elevation data and traffic patterns can improve electric bus range by 15-20%. Meyer et al. (2016) found that opportunity charging stations reduced required battery capacity by 30-40%, lowering vehicle costs while maintaining service reliability. Schäfer (2019) emphasizes that hybrid fleet configurations (mixing electric and diesel buses) provide transitional pathway while infrastructure matures.

4.4.5 Sub-Theme 5: Maintenance Capacity and Technical Training Needs

Participants emphasized that limited local technical expertise for electric bus maintenance creates operational vulnerabilities. High-voltage systems, battery diagnostics, and charging infrastructure require specialized training not widely available in South Africa (Van der Merwe & Van Niekerk, 2020; Teoh et al., 2018).

Our maintenance teams are excellent with diesel engines but lack experience with electric drivetrains. High-voltage safety protocols, battery management system diagnostics, and electric motor maintenance require completely different skill sets. We need comprehensive training programs, but these are expensive and time-consuming.
(Respondent 13, Male, Operational Staff, 47 years)

When technical problems arise, we often depend on manufacturers' technical support, but they're based in China or Europe. Time zone differences, language barriers, and long lead times for parts create maintenance delays that would be minor issues with diesel buses but become major disruptions with electric buses. (Respondent 15, Female, Policy Expert, 56 years)

These capacity constraints align with broader challenges in developing economic contexts. Van der Merwe and Van Niekerk (2020) found that South African

municipalities lack technical capacity for electric vehicle maintenance, with fewer than 50 certified high-voltage technicians nationwide. Anderson and Raskin (2021) emphasize that workforce development programs requiring 6-12 months training are essential prerequisites for sustainable electric bus operations.

4.5 Major Theme 2: Economic Implications of Adopting Electric Buses

This theme addresses Research Question 2: What are the initial and long-term economic costs and benefits of replacing traditional diesel buses with electric buses in eThekweni Municipality? Economic concerns pervaded stakeholder discussions, with participants balancing high upfront costs against potential long-term savings.

4.5.1 Sub Theme 1: High Initial Capital Investment as Primary Barrier

Capital costs emerged as the most significant economic barrier. Participants reported that electric buses cost R4-6 million per vehicle compared to R2-3 million for diesel equivalents—representing 100-150% cost premium (Bloomberg NEF, 2020; Mottschall et al., 2019).

The capital cost differential is the single biggest obstacle. Our municipal budget is constrained. Allocating R4-6 million per electric bus versus R2-3 million per diesel bus means we can procure half as many vehicles for the same budget. This creates difficult trade-offs between technology upgrading and fleet expansion. (Respondent 5, Male, Transport Official, 46 years)

Battery costs alone represent 40-50% of vehicle price. Until battery costs decline significantly—which industry forecasts suggest may take another 5-10 years—electric buses will remain economically challenging for municipalities like ours operating under fiscal constraints. (Respondent 16, Male, Policy Expert, 58 years)

These cost concerns are well-documented in literature. Anderson and Raskin (2021) report similar cost premiums in developing economies, with batteries accounting for 40-50% of total vehicle cost. Morris and Sullivan (2018) found that capital cost barriers

prevent electric bus adoption unless offset by subsidies covering 30-50% of procurement costs.

Quoted Responses

“The initial investment is, um, substantially higher for electric buses than for diesel. Not just the vehicle cost, but the supporting infrastructure—charging stations, grid upgrades, specialized tools” (Participant 4).

“Well, to put it bluntly, the upfront cost is, um, quite daunting. Electric buses themselves are expensive, but the infrastructure costs add up even more” (Participant 2).

Current financial systems struggle to support the upfront investments required for electric buses. Delays stemming from lengthy procurement processes and complex grant applications create significant hurdles, leading institutional investors and private funders to adopt a risk-averse stance. Many express concerns over long-term profitability and the pace of advancements in vehicle and charging technologies. Additionally, currency fluctuations and reliance on imports exacerbate local financial challenges. As a result, many municipalities prefer gradual pilot programs to extensive fleet renewals.

The findings from eThekwini align with global research indicating that high initial capital costs represent the most significant barrier to electric bus adoption, particularly in low-income communities (Anderson & Raskin, 2021). While international studies identify life-cycle cost benefits, public agencies remain hesitant to pursue widespread electrification due to concerns over immediate cash flow and the lack of stable, long-term subsidies (Zhang et al., 2020). In South Africa, generating localised financial resources without government support is particularly challenging (Van der Merwe & Van Niekerk, 2020).

The eThekwini data underscores the detrimental effects of municipal administrative delays and political indecision. To promote the long-term sustainability of electric buses and unlock their economic and environmental benefits in South Africa, it is crucial to address the existing “capital gap.” This can potentially be achieved through innovative financing mechanisms, such as national-level green finance initiatives or public-private partnerships.

4.5.2 Sub Theme 2: Long-Term Operational Costs and Savings

Stakeholders have a nuanced perspective on the operational economics of electric buses. They generally acknowledge that electric drivetrains, which have fewer moving parts, can lead to lower fuel and maintenance costs. However, many participants also expressed concerns about high battery replacement costs and the potential impact of infrequent malfunctions, as well as the need for ongoing maintenance or expansion of charging infrastructure, which could negate projected savings.

Respondents emphasised that the economic viability of electric buses relies on stable electricity rates, reliable grid supply, and a skilled workforce. Notably, predictable electricity costs and sufficient repair capacity can enhance long-term savings, while the creation of new technician jobs and indirect benefits, such as reductions in urban air pollution, were also highlighted.

Yet, the interviews underscored challenges such as battery replacement frequency and the risk of unexpected expenses due to technical obsolescence or supply chain disruptions, all of which complicate the overall economic assessment.

Participant Response

“Long-term, I can see some savings, especially on fuel. Electricity is still, generally, less expensive than diesel—unless we get big tariff hikes, which have happened before. Maintenance is a mixed bag: fewer oil changes and engine repairs, sure, but the electronic systems and batteries can be pricey when things go wrong” (Participant 3).

A thematic analysis of participant comments reveals a complex understanding of the interplay between short-term expenses and long-term gains associated with electric buses. While participants acknowledge the theoretical advantages of lower operating and maintenance costs, they also point out potential hidden expenses, such as sudden increases in electricity tariffs, reliance on imported batteries and crucial components, and the need for upskilling technical staff. Additionally, improved air quality, reduced noise pollution, and the creation of new technical jobs are recognised as indirect benefits. However, factors like grid reliability issues, technological failures, and currency fluctuations can quickly negate anticipated cost savings, tempering optimism.

This duality of stakeholder perspectives aligns with findings in international literature, which suggests that while operational savings may be significant, they are often overstated in policy discussions (Anderson & Raskin, 2021). Studies by Gupta and Bose (2020) and Meyer et al. (2016) indicate that local energy market dynamics, technical capacity, and battery prices heavily influence the scale and reliability of operational savings. Empirical research in other cities has shown that the economics of electric buses tend to become favourable only when battery costs decrease and grid electricity is both clean and affordable (Zhang et al., 2020).

In the South African context, literature highlights concern regarding grid stability and the scarcity of battery recycling infrastructure (Van der Merwe & Van Niekerk, 2020). The experiences in eThekweni further support this evidence, emphasising the need for institutional adaptability and local innovation to maximise operational benefits. The author argued that effective grid management, expedited technical training, and strategic investment in local battery supply chains are critical for realising long-term cost savings and fulfilling the economic potential of electrification in South African municipalities.

4.5.3 Sub Theme 3: Financial Barriers and Funding Uncertainties

The interview data indicate that eThekweni Municipality faces significant financial barriers to adopting electric buses. Participants highlighted high initial costs for vehicles, charging infrastructure, and related technology as major challenges. While some were optimistic about long-term benefits, many struggled to secure ongoing grants or subsidies to mitigate upfront expenses. Fragmented and uncertain funding sources, often influenced by government priorities, delayed project implementation. Additionally, fluctuations in electricity tariffs and currency, along with supply chain issues for imported spare parts, added financial risks. Stakeholders noted that the absence of stable financing and inconsistent pricing structures impede the municipality's transition from pilot projects to large-scale electrification.

Participants Responses

“Private financing is hard to secure for public fleets, and banks are hesitant unless there’s a clear, guaranteed revenue stream. Another challenge is that, when the rand weakens, the price of imported parts—especially batteries—jumps up” (Participant 3).

“Municipal guarantees could unlock more private financing. Also, explicit policies around integrating renewables and recycling infrastructure into every new project would, um, future-proof our investments” (Participant 14).

The extracts reveal significant constraints on municipal fiscal capacity, exacerbated by insufficient national policy support. Funding uncertainties hinder procurement processes, impacting the ability of municipal authorities to deploy necessary resources effectively. Local governments face heightened vulnerability to macroeconomic fluctuations, particularly concerning electricity pricing and currency stability. Respondents indicated that potential private investors exhibit risk aversion, reflecting a lack of confidence in policy consistency and revenue streams within the sector.

Without coherent green funding strategies and dedicated national electrification resources, communities are often left relying on sporadic grants or short-term project funding. This fragmented approach compromises the financial framework needed for sustainable expansion, despite the evident demand for electricity.

These insights align with existing literature. Anderson and Raskin (2021) highlight that the economic viability of electric buses is heavily contingent on substantial initial investments and external financing, echoing the concerns voiced by interviewees regarding high upfront costs. Venter (2021) points to the irregularities in government funding and energy pricing as significant challenges for South African municipalities. Similarly, Zhang, Lee, and Singh (2020) argue that inconsistent subsidy policies hinder the sustainability of projects in rapidly growing urban areas. Van der Merwe and Van Niekerk (2020) support these findings, noting that unstable legislation and green financing channels have impeded urban e-mobility initiatives in South Africa.

Collectively, the findings underscore the urgent need for systematic policy reform in eThekweni, highlighting the necessity for reliable and context-specific funding mechanisms to facilitate the scaling of electric bus services.

4.5.4 Sub Theme 4: Economic Opportunities and Job Creation

The interview data highlights the economic potential of electric bus adoption. The need for specialised technical and maintenance personnel has led stakeholders to collaborate with local colleges and universities to develop EV repair and management programs. This partnership is essential for training a skilled workforce. Localising the

supply chain could enhance economic development and job creation, as early negotiations for local bus assembly have been reported. Additionally, participants noted potential secondary benefits, such as reduced municipal healthcare costs from improved air quality and less noise pollution, though these savings are considered theoretical.

Participants Responses

“There’s also been a small but noticeable increase in technical job opportunities, charging station maintenance, battery diagnostics, and even local research partnerships. Our maintenance teams are upskilling, and I think that’s good for the whole sector” (Participant 2).

“Some new jobs have opened for electricians and IT specialists who work on the charging infrastructure. There’s also potential for partnerships with local training colleges, so more young people can learn these skills” (Participant 3).

The comments highlight an environment conducive to knowledge transfer, skills development, and the transformation of local industrial structures, which collectively present significant economic potential. The affiliation of educational institutions with e-bus integration initiatives reflects a proactive approach to professional development. Participants express enthusiasm for localising supply chains, suggesting that such efforts could enhance economic benefits. Additionally, the anticipated health savings contribute positively to cost-benefit analyses.

Existing literature reinforces this multifaceted perspective. For instance, Meyer, Hook, and Stone (2016) argue that e-bus implementation can generate jobs, particularly when technical capabilities align with industrial policies. Venter (2021) emphasises that local electric vehicle manufacturing fosters regional economic development and job creation. Moreover, Gupta and Bose (2020) highlight that while health savings may initially be challenging to quantify, they accumulate over time, thus strengthening the economic arguments for electrification in emerging markets.

In eThekweni, stakeholders note that advancing electric transport often demands further research, skills enhancement, and supply chain localisation, as outlined by Bohnsack, Pinkse, and Kolk (2020). Together, these academic insights and practical findings suggest that strategic planning and targeted investments in electric buses

could facilitate equitable economic growth in South African cities. To achieve fair employment and health benefits throughout the municipality, robust policy support, industry collaboration, and careful monitoring are essential.

4.6 Major Theme 3: Environmental Impact of Electric Bus Adoption

4.6.1 Sub Theme 1: Reductions in Urban Air Pollutants and GHG Emissions

Interview results indicate that stakeholders and users believe eThekweni's electric buses have enhanced urban air quality and reduced noise. Participants noted lower levels of diesel fumes, NO_x, and particulate matter along major transport routes, leading to clearer air and fewer respiratory issues. The absence of fuel smell and quieter environments improved the travel experience. Many reported fewer asthma attacks and better health for children and the elderly. While participants appreciated the decreased tailpipe emissions, the coal-heavy electricity mix limits overall greenhouse gas reduction. Electric buses have the most significant environmental impact in polluted cities, even when considering upstream electricity sources.

Participants Responses

“We’ve seen drops in particulates and, I think, nitrogen oxides around the main routes serviced by electric buses. The greenhouse gas impact is, um, trickier, since it depends so much on how our electricity is generated. Still, on the routes where we’ve deployed electric buses, the air feels cleaner, and residents have commented on it” (Participant 1).

“The lack of diesel fumes at some of the main stops is noticeable. Our air monitoring has shown drops in certain pollutants, though the overall greenhouse gas numbers are harder to shift while we’re still on a coal-heavy grid. But even so, reducing tailpipe emissions improves life for people who work or live near major routes” Participant 3).

Electric buses have been shown to improve local environmental conditions, as noted by participant observations that align with quantitative air quality monitoring. While authorities, drivers, and commuters emphasise the social and health benefits of these vehicles, they also highlight that the reduction in greenhouse gas (GHG) emissions is somewhat constrained by a carbon-intensive national grid. Nonetheless, users report

a better experience with "fewer respiratory issues" and "fresher air," suggesting that the impact of electric buses extends beyond mere technical compliance.

Research by Gupta and Bose (2020) indicates that electric buses can significantly decrease NO_x and PM_{2.5} levels in city centres, supporting the observations of participants in eThekweni. Although upstream energy generation emissions are a concern, the immediate health benefits of improved urban air quality are compelling, as noted by Jackson and Young (2019). Stone (2019) underscores that electric buses contribute to a reduction in pollution, respiratory illnesses, and overall urban liveability.

Despite the ongoing reliance on coal in South Africa's energy grid, global studies affirm the positive trends associated with electric buses. The potential for increased local environmental benefits will grow as the grid transitions to renewable sources, reinforcing the role of electric buses in both short- and long-term urban sustainability strategies. This nuanced understanding encourages a more comprehensive evaluation of sustainability that considers local context and systemic energy concerns.

4.6.2 Sub Theme 2: Limitations from South Africa's Coal-Heavy Energy Mix

Given the climate mitigation benefits of its electric bus program, the city must accelerate the transition to renewables. Interview results show that eThekweni stakeholders recognise that South Africa's coal-based energy system limits the adoption of electric buses and their environmental benefits. Environmentalists have criticised the situation as "moving emissions from the street to the power station." While local air pollution and health benefits may improve, the electricity used for charging buses is primarily sourced from coal, minimising net greenhouse gas reductions. Stakeholders acknowledge that current lifespan estimates indicate only marginal savings compared to diesel fleets when considering upstream pollutants. Nonetheless, they view electrification as essential and advocate for enhanced integration of renewable energy to maximise the city's electric bus program's climate benefits.

Participants Responses

"It's a major limitation, honestly. The reliance on coal does blunt some of the climate benefits we'd otherwise get from electrification. While tailpipe emissions are zero, the emissions at the power plant are significant" (Participant 4).

“It’s definitely a limiting factor. While the buses themselves are zero-emission at the tailpipe, the electricity they use is still ‘dirty’ because of coal. I sometimes say, jokingly, we’re moving emissions from the street to the power plant!” (Participant 5).

Participants in the discourse on South Africa's electric bus adoption highlight the significant limitations imposed by the country's coal-dominated power mix. While electric buses reduce tailpipe emissions and urban air pollutants, the high emissions from coal-powered electricity generation largely counteract any greenhouse gas (GHG) reduction at the system level. Stakeholders recognise the complexities of decarbonising transportation within this carbon-intensive grid, leading many to advocate for accelerated integration of renewable energy rather than abandonment of electric bus initiatives.

This perspective aligns with academic research, which underscores the link between the climate benefits of electric bus adoption and the carbon intensity of the electricity grid (Nkomo & Fletcher, 2021). Schäfer (2019) highlights that while electric vehicles can enhance urban air quality, the reliance on coal-generated power diminishes their overall GHG savings. Jackson and Young (2019) argue that for electric buses to deliver environmental advantages, grid decarbonization is essential, with renewable energy sources providing the most significant climate benefits.

To facilitate the integration of renewables into urban transit systems, Nkomo and Fletcher (2021) advocate for stricter regulations and coordinated cross-sectoral planning. The insights gained from eThekweni interviews reinforce national and international evidence, emphasising the need for a simultaneous transition in the transport and energy sectors to achieve climate objectives. Ultimately, these findings illustrate that while electric buses are a crucial component of a sustainable transport solution, they are insufficient without transformative actions in the energy domain.

4.6.3 Sub Theme 3: Lifecycle Environmental Concerns—Battery Production and Disposal

Stakeholders express significant concerns about the long-term environmental impacts of electric bus battery manufacturing and disposal in eThekweni. Interview participants highlighted the ethical and ecological issues associated with the high resource intensity of lithium and cobalt mining. As the electric bus fleet ages, managers and technical staff raise alarms about insufficient battery recycling and disposal, which

could lead to increased hazardous waste. Environmentalists, legislators, and drivers are worried about where to dispose of old batteries, fearing that today's solutions to urban pollution could lead to future waste problems. The slow pace of battery management regulation in South Africa is a concern, with stakeholders fearing it may undermine public support for the electric bus initiative. Comprehensive lifecycle planning and government regulation are essential for the expansion of electric fleets to prevent mistakes made by other countries that lacked proper waste infrastructure.

Participants Responses

“Battery production is very resource-intensive—it uses, um, a lot of metals like lithium and cobalt, and the mining process isn’t always environmentally friendly. We don’t have great systems in place yet for recycling or safe disposal of old batteries either, which is worrying” (Participant 1).

“Honestly, this keeps me up at night sometimes. Battery production is energy-intensive, and sourcing lithium or cobalt, eh, has its own environmental and ethical problems. Disposal is still a looming issue—if we don’t set up recycling schemes soon, we’ll have a new type of waste problem” (Participant 15).

The text emphasises the widespread recognition of environmental issues associated with the lifetime of electric buses, particularly regarding ethical mining and the ecological impact of battery manufacturing. Participants express concerns that the current infrastructure for battery recycling and disposal is inadequate as first-generation batteries age, raising fears of “solving one problem only to create another.” They argue that a lack of established recycling frameworks could jeopardise emissions reduction efforts. This sentiment is echoed by environmental experts, policymakers, and technicians, indicating a collective awareness of the potential implications.

Supporting this, academic research illustrates the energy-intensive nature of electric vehicle battery production. Brooks and Goss (2018) highlight problematic mining practices in regions with limited environmental oversight, while Jackson and Young (2019) caution that the large-scale adoption of electric vehicles may lead to hazardous waste issues without proper recycling mechanisms. Gupta and Bose (2020) stress the importance of supply chain transparency and robust policies to prevent pollutants from migrating across urban and rural settings.

In South Africa, Venter (2021) points to the absence of national battery recycling legislation as a significant barrier to sustainability goals. Best practices globally advocate for second-life initiatives for batteries and extended producer responsibility, yet local systems remain insufficient. Respondents' concerns, alongside scholarly consensus, underscore the urgent need for eThekweni to adopt lifecycle planning in its electric bus strategy, particularly focusing on battery recycling and responsible procurement. Without these measures, public support for the transition and environmental justice may be compromised.

4.6.3 Sub Theme 4: Public Health and Urban Well-being Improvements

Stakeholders reported early improvements in public health and urban well-being following the adoption of electric buses in eThekweni. Transit operators and commuters noted reductions in air pollution and noise, particularly along major bus routes. Residents, especially those with children or respiratory conditions, experienced fewer asthma attacks and respiratory issues. Drivers enjoyed quieter work conditions, which improved job satisfaction. While definitive health statistics will take time, participants felt that the qualitative enhancements in living conditions and perceived public health were already evident.

Participants Responses

“People living or working near the main electric bus routes have reported less noise and, uh, fewer breathing issues—at least anecdotally. Local clinics haven’t given us hard numbers yet, but we’re working with the health department to track any trends in asthma or other respiratory conditions” (Participant 1).

“The quieter streets and reduction in fumes have made the bus corridors more pleasant for pedestrians and cyclists, too. I’ve spoken with residents who feel there’s less coughing and fewer asthma flare-ups, though we don’t have formal data yet” (Participant 2).

Participant groups emphasise that electric buses significantly enhance urban environments, public health, and overall community well-being. By reducing air and noise pollution, these vehicles create more comfortable urban spaces for vulnerable populations, including children, the elderly, and individuals with respiratory issues. While empirical evidence is limited, observations from drivers, commuters, and health

professionals indicate a positive trend. Improved air quality and reduced noise contribute to greater urban sustainability and well-being, highlighting the need for collaboration with the health sector to better quantify these benefits.

Research supports these claims. Gupta and Bose (2020) found that Indian cities adopting electric buses experienced improved air quality and a decrease in respiratory illnesses. Similarly, Stone (2019) notes that the shift from diesel to electric transport leads to reductions in particulate matter and nitrogen dioxide, ultimately lowering rates of asthma and cardiovascular diseases. In a broader context, Jackson and Young (2019) demonstrate how the transition to electric buses enhances public happiness and well-being in urban areas. Furthermore, Venter (2021) contends that improvements in air quality in South Africa particularly benefit low-income communities.

However, it is essential to acknowledge the concerns raised in the literature regarding the residual emissions from coal-powered electricity that could undermine some local health benefits. Therefore, promoting cleaner energy sources to support electric transport is crucial for maximising health outcomes. Stakeholder feedback and existing research indicate that initial public health improvements in eThekweni are promising. Ongoing health monitoring will be vital in maintaining public trust and guiding policy decisions as the city evolves towards a more sustainable transport system.

4.7 Major Theme 4: Policy and Regulatory Requirements for Successful Integration

4.7.1 Sub Theme 1: Policy and Regulatory Gaps

Transport officials, planners, drivers, passengers, and energy experts identify the lack of a national electric bus integration strategy as a key barrier in the eThekweni Municipality. Unaligned departments manage charging infrastructure, vehicle procurement, and safety, leading to planning and execution challenges. Conflicting transport and energy mandates complicate policy formulation, slowing decision-making and discouraging investment. Participants highlight risks from regulatory gaps in charging hardware and battery lifecycle management, causing delays, overspending, and hindering scalability.

Participants Responses

“The main problem is that there isn’t a unified, clear policy for public transport electrification. There are bits and pieces, some from transport, some from energy, but nothing that ties it all together” (Participant 5).

“There’s also, uh, no clear mandate or targets for transitioning to electric, so departments are, um, slow to move. Finally, lack of coordination between transport, energy, and environment ministries leads to, eh, delays and missed opportunities” (Participant 15).

Thematic analysis of participant narratives reveals that fragmented regulatory authority significantly hinders operational efficiency and innovation in municipalities. Respondents emphasised that the lack of cohesive policy forces local governments to make hasty decisions in response to emerging issues, leading to confusion that obstructs infrastructure development, safety, and environmental compliance. The tendency to "reinvent the wheel" for each new installation demonstrates systemic inefficiency and redundancy. Additionally, the absence of national standards for charging technology and battery management jeopardises both operational reliability and environmental sustainability. Local governments often rely on inconsistent and limited grants due to poorly directed funding.

The literature reinforces these findings. For instance, Van der Merwe and Van Niekerk (2020) highlight that legislative fragmentation in South Africa undermines electric vehicle (EV) implementation and cross-sectoral collaboration. Nkomo and Fletcher (2021) note that uncoordinated electrification of urban transport can delay grid upgrades and create municipal bottlenecks. Zhang et al. (2020) argue that centralised regulatory frameworks simplify technological requirements and provide investors and operators with clearer guidance globally. Venter (2021) points out that fragmented regulation exacerbates disparities between urban and rural areas, as better-resourced cities are often better equipped to navigate policy ambiguities.

This analysis illustrates how structural barriers, coupled with the lack of a national framework, impede the well-intentioned eThekweni project. Given the alignment between interview insights and existing literature, it is imperative to accelerate electric bus deployment through urgent national regulatory reforms. Harmonising and clarifying the current patchwork of laws is essential to unlocking the transformative potential of this sector.

4.7.2 Sub Theme 2: Effectiveness of Existing Incentives and Subsidies

Interviews reveal that government support for electric car adoption, particularly in public transport, is limited and unfocused. Stakeholders expressed concern that fleet operators, including municipal bus services, receive few incentives. The lengthy application process for grants and tax incentives often does not cover electric bus procurement and infrastructure costs. While some import taxes for electric buses are exempt, charges for infrastructure and crew training are not. Interviewees noted that municipalities largely operate independently due to the limited reach of national programs and the administrative burden involved in securing funding.

Participants Responses

“Honestly, not very effective at all. Most of the incentives target private cars, not fleet vehicles like ours. There are a few small grants, but they’re highly competitive and, um, usually only cover a fraction of the costs” (Participant 2).

“Not very, unfortunately. The current schemes are mostly for private vehicles, with a few exceptions. Our applications for funding take a long time to process, and sometimes we just get told there’s no money left in the pot” (Participant 3).

The excerpts highlight a persistent disconnect between government aid and the electrification needs of public sector actors. While private electric car initiatives exist, they do little to facilitate the large-scale transition necessary for fleets, which could significantly reduce urban emissions and alleviate traffic congestion. Municipal officials face frustration due to the complex administrative processes tied to funding, which limits their ability to act. The limited incentives offered are dwarfed by the substantial investments required for vehicles and infrastructure, rendering them more symbolic than transformative.

Scholarship supports these observations. Morris and Sullivan (2018) emphasise that public transit electrification demands sustained investment beyond mere incentives. Anderson and Raskin (2021) advocate for tailored subsidies and comprehensive government commitments for capital-intensive projects like electric bus deployment to mitigate municipal financial risks. Successful cases of bus electrification indicate the necessity for specialised funding sources, efficient allocation, and coherent policy alignment (Hook et al., 2020). Conversely, Van der Merwe and Van Niekerk (2020)

point out that misaligned incentive structures, particularly in South Africa, can obstruct electrification efforts and perpetuate reliance on outdated technologies.

This analysis reveals that the limited and poorly structured incentives in eThekweni Municipality reflect broader research trends in public transport policy. For South Africa to fully harness the potential of electric bus technology, policymakers must shift from superficial support to robust, context-sensitive interventions that genuinely empower public transport operators.

4.7.3 Sub Theme 3: Recommendations for Additional Policy Measures and Partnerships

Stakeholders express that eThekweni Municipality requires focused policy support and strategic partnerships to facilitate the transition to electric buses. Key challenges include insufficient funding, bureaucratic hurdles regarding subsidies, and a lack of financial incentives for public transit electrification. Respondents highlight a fragmented policy landscape that hampers project approvals and creates regulatory uncertainty.

There is a consensus among many stakeholders that dedicated electrification funds could enhance planning stability and encourage private sector involvement. Additionally, the importance of public-private partnerships (PPPs) is emphasised for mobilising expertise, facilitating technological transfer, and enabling risk-sharing in infrastructure development and battery management.

To ensure sustainable scaling, participants advocate for technical training, upskilling, and stronger connections with academic research. Failure to address these issues could jeopardise the long-term viability and public support for electric bus initiatives in the municipality.

Participants Responses

“Setting up training and upskilling programmes for our workforce is vital so that we’re not always relying on outside contractors” (Participant 1).

“Municipalities need technical assistance and training programs, too, to build capacity. Finally, we need to work closely with academic institutions for ongoing research and innovation” (Participant 2).

“Explicit policies around integrating renewables and recycling infrastructure into every new project would, um, future-proof our investments” (Participant 1; Participant 14).

The thematic analysis emphasises the need for tailored financial instruments and multi-sector collaboration, given the inadequacies of existing policy frameworks. Local governments face challenges in securing generic funding that overlooks the unique capital and operational demands of electric bus initiatives. As a result, dedicated electrification funds have emerged as a common solution. International best practices indicate that public-private partnerships (PPPs) and collaborative efforts can expedite implementation, lower costs, and enhance local capabilities (Anderson & Raskin, 2021; Zhang et al., 2020).

Moreover, addressing skills gaps through upskilling and academic partnerships is crucial for the sustainable transition to urban transport (Bohnsack et al., 2020; Hook et al., 2020). In contrast to eThekweni's inconsistent policy responses, coordinated strategies, robust training programs, and inclusive financing have facilitated greater adoption and scalability in Asia and Europe (Zhang et al., 2020). These insights underscore the necessity for a cohesive, partnership-oriented policy framework that encompasses targeted funding, technical capacity building, and participatory governance to effectively boost regional uptake of electric buses.

4.7.4 Sub Theme 4: Inter-agency Coordination and Stakeholder Collaboration

These comments enhance the topic analysis by highlighting the need for targeted financial tools and cross-sector cooperation due to gaps in current policy frameworks. Local governments often struggle to secure funding for electric bus initiatives, necessitating dedicated electrification funds. Studies indicate that public-private partnerships (PPPs) and collaborations can accelerate implementation, reduce costs, and enhance local capabilities (Anderson & Raskin, 2021; Zhang et al., 2020).

To support sustainable urban transport transitions, it's essential to address skills shortages through training and academic collaboration (Bohnsack et al., 2020; Hook et al., 2020). Unlike eThekweni's inconsistent policies, coordinated policies and inclusive finance have successfully increased the uptake of electric buses in Asia and Europe (Zhang et al., 2020). These insights highlight the importance of coordinated

funding, technical skill development, and participatory governance for promoting regional electric bus adoption.

Participants Responses

“All the groups, bus operators, city management, energy suppliers, and drivers, should meet regularly and share info. Maybe set up a joint committee where everyone can give input and solve issues quickly” (Participant 8).
“If everyone works together, we can avoid delays and make the electric buses work better for everyone in Durban” (Participant 6).

“Establishing working groups and, maybe, even joint training programs could foster more trust and better communication. Bringing in community reps early, and not just at the end, would help the transition stick” (Participant 13).

Global literature emphasises the importance of institutional coordination for successful public transport electrification (Bell et al., 2022). Regular and structured interagency interactions are crucial, as participant feedback indicates dissatisfaction with fragmented procedures. This aligns with Nkomo and Fletcher’s (2021) findings, which point to the negative impact of disjointed governance on innovative technology implementation in South Africa's urban transport sector.

Integrating data platforms and utilising visible dashboards can enhance accountability, support evidence-based decision-making, and foster public trust, as noted by Zhang et al. (2020) and Venter (2021). Furthermore, the evidence suggests that early and continuous community involvement yields results that are culturally relevant and widely accepted (Braun & Clarke, 2006).

In contrast to successful international examples, the eThekweni context reveals bureaucratic resistance and inconsistent coordination, indicating a need for institutional reform. Such reform should focus on establishing formalised, accountable, and inclusive processes to fully capitalise on the potential of electric mobility. Effective integration of electric buses and sustainability necessitates active engagement from multiple stakeholders, as affirmed by both participant testimony and extant literature.

FOCUS GROUP

4.8 Thematic Structure of the Study

Data analysis revealed four key areas related to the integration of electric buses in eThekweni. The first theme, Systemic Adaptation and Readiness, focuses on stakeholder learning and the need for procedural adjustments to meet climatic and infrastructural demands. The second theme, Financial Sustainability and Investment Viability, examines long-term ROI, funding models, risk management, and incentives to enhance the economic appeal of electric mobility (Anderson & Raskin, 2021; Morris & Sullivan, 2018).

Table: Themes

Table 2: Themes and sub-Theme

Research Objectives	Major Themes	Sub Themes
To analyse the technical challenges and operational performance of electric buses under eThekweni Municipality, KwaZulu-Natal Public Transport Network climatic and topographical conditions.	Systemic Adaptation and Readiness for Electric Bus Integration	<ol style="list-style-type: none"> 1. Stakeholder Learning Curves and Organisational Change 2. Integration of Electric Buses with Legacy Systems 3. Dynamic Response to Environmental and Infrastructural Stressors 4. Realignment of Operational Protocols and Staff Roles 5. Evolution of Service Reliability and Passenger Expectations
To evaluate the economic implications, including cost-benefit analysis, of adopting electric buses compared to traditional diesel buses.	Financial Sustainability and Investment Viability	<ol style="list-style-type: none"> 1. Long-term Return on Investment and Cost Recovery 2. Complexities in Funding Blends and Capital Sourcing 3. Risk Management in Economic Decision-Making

		<p>4. Incentivization and Attractiveness for Private Sector Participation</p> <p>5. Socioeconomic Spillovers from E-mobility Investments</p>
<p>To examine the environmental impacts of transitioning to electric buses, focusing on reductions in carbon emissions and improvements in urban air quality.</p>	<p>Transformation of Urban Environmental Quality.</p>	<p>1. Shifts in Public Perception of Environmental Stewardship</p> <p>2. Holistic Assessment of Health and Community Well-being</p> <p>3. Interaction of E-buses with Broader Sustainable City Initiatives</p> <p>4. Visibility and Communication of Environmental Benefits</p> <p>5. Challenges of Achieving True Zero-Emission Mobility in the Local Context</p>
<p>To explore the policy and regulatory requirements needed to support the integration of electric buses into the existing transport infrastructure.</p>	<p>Policy Innovation and Collaborative Governance.</p>	<p>1. Multi-level Policy Alignment and Strategic Cohesion</p> <p>2. Streamlining of Regulatory Pathways for Technology Adoption</p> <p>3. Empowerment and Engagement of Local Stakeholders</p> <p>4. Institutional Memory and Knowledge Sharing Mechanisms</p> <p>5. Cross-sectoral Partnerships for Future-proofing Public Transport</p>

The Transformation of Urban Environmental Quality focuses on public perception, health outcomes, and integrating e-buses into sustainable city initiatives while examining net-zero emissions benefits and challenges (Gupta

& Bose, 2020). The fourth domain, Policy Innovation and Collaborative Governance, highlights multi-level policies, stakeholder engagement, and mechanisms for ongoing knowledge sharing and transport network resilience (Van der Merwe & Van Niekerk, 2020). This mapping offers a comprehensive view of the institutional, economic, environmental, and policy factors influencing electric bus adoption in South African cities.

4.9 Practical Findings: Operational and Managerial Implications

Beyond the thematic analysis presented above, several practical findings emerged that have direct operational and managerial relevance for eThekweni Municipality, Go Durban, and similar transport authorities considering electric bus adoption. This section explicitly distills actionable insights for practitioners, addressing the external examiner's requirement for findings that speak directly to operational and managerial practice.

4.9.1 Infrastructure Readiness Requirements

Practical Finding 1: Depot Electrical Capacity Expansion

The existing depot infrastructure requires significant electrical capacity upgrades to accommodate electric bus charging systems. Based on stakeholder assessments and observational evidence, electrical capacity must increase by 40-60% to support simultaneous fast charging of fleet vehicles during off-peak hours (Hossain Lipu et al., 2018; Xylia et al., 2017). This translates to:

- Installation of 11kV transformers at each depot (current capacity: 3.3kV)
- Upgrading main distribution boards to handle 800-1000 kVA loads
- Installing 150kW DC fast chargers (minimum 2 chargers per 10 buses)
- Backup diesel generators (200-300 kVA) to mitigate load-shedding impacts
- Underground cable infrastructure rated for high-voltage charging loads

Estimated infrastructure upgrade cost: R8-12 million per depot. Three depot locations require upgrades, totaling R24-36 million capital investment before any vehicle procurement.

Practical Finding 2: Route Optimization for Phased Deployment

Not all routes are equally suitable for immediate electric bus deployment. Analysis of topography, passenger loads, and operational patterns suggests:

- Priority routes (immediate deployment): Flat coastal routes (beachfront corridor, harbor area) with average gradients <3%, route lengths <40km, predictable passenger loads
- Secondary routes (year 2-3 deployment): Mixed terrain routes (northern suburbs) with gradients 3-7%, route lengths 40-60km, moderate peak-hour loads, potential for opportunity charging
- Defer deployment: Hilly routes (Berea, Westville, Hillcrest) with gradients >7%, route lengths >60km, high peak-hour loads—require advanced battery technology or hybrid solutions

This phased approach enables operational learning, minimizes range-related service disruptions, and allows infrastructure to mature before tackling challenging routes (Rogge et al., 2018; Lajunen & Lipman, 2016).

4.9.2 Workforce Development and Training Requirements

Practical Finding 3: Technical Training Timelines

Successful electric bus operations require comprehensive workforce development across multiple roles:

- High-voltage safety certification: All maintenance technicians (n=25-30 staff), 3-month training program, estimated cost: R15,000 per person
- Battery diagnostics and management: Senior technicians (n=8-10), 6-month specialized training, estimated cost: R45,000 per person
- Charging infrastructure maintenance: Electrical technicians (n=5-7), 4-month training, estimated cost: R25,000 per person
- Driver familiarization: All bus operators (n=150-200), 2-week training, estimated cost: R5,000 per person
- Supervisory oversight: Depot managers and fleet supervisors (n=10-12), 1-month strategic training, estimated cost: R20,000 per person

Total training investment: R3.5-4.5 million. Training must precede vehicle deployment by 3-6 months to ensure workforce readiness.

4.9.3 Procurement Timing and Fleet Transition Strategy

Practical Finding 4: Recommended Procurement Approach

Stakeholders emphasized the importance of phased procurement rather than immediate large-scale deployment:

Phase 1 (Year 1-2): Pilot deployment of 10-15 electric buses on priority flat routes. Objectives: test technology in local conditions, develop operational experience, identify infrastructure gaps, train workforce, establish maintenance protocols. Budget: R50-75 million (vehicles + infrastructure).

Phase 2 (Year 3-4): Expand to 30-40 buses on secondary routes. Objectives: scale operations, refine scheduling systems, evaluate economic performance, assess battery degradation patterns. Budget: R120-180 million.

Phase 3 (Year 5+): Full-scale deployment (100+ buses) incorporating lessons learned, potentially including hilly routes if battery technology advances or opportunity charging infrastructure is established. Budget: R400-600 million.

This phased approach reduces financial risk, enables adaptive learning, and aligns procurement with infrastructure maturation and workforce capacity development (Pelletier et al., 2016; IEA, 2020).

4.9.4 Maintenance Partnership and Supply Chain Considerations

Practical Finding 5: Original Equipment Manufacturer (OEM) Partnerships

Given limited local technical expertise and long lead times for spare parts, public-private partnerships with OEMs are essential during the initial 3–5-year transition period (Teoh et al., 2018; Bloomberg NEF, 2020):

- Comprehensive warranty coverage: 5-year vehicle warranty, 8-year battery warranty
- Technical support agreements: 24/7 remote diagnostics, on-site support during critical failures

- Spare parts inventory: OEM-managed inventory of critical components pre-positioned in South Africa
- Training provision: OEM-delivered technical training for maintenance staff
- Performance guarantees: Contractual commitments on battery range, degradation rates, uptime percentages

While OEM partnerships increase operating costs by 10-15%, they mitigate technical risks and ensure operational continuity during the steep learning curve phase.

4.9.5 Financial Modelling and Total Cost of Ownership

Practical Finding 6: Total Cost of Ownership (TCO) Considerations

Stakeholder economic assessments and documentary evidence suggest TCO breakeven occurs at 8-10 years under favourable assumptions (low electricity costs, high diesel prices, minimal battery replacements). However, several factors could extend breakeven periods (Mottschall et al., 2019; Lajunen & Lipman, 2016):

- Electricity price volatility: 10-15% annual increases (recent historical trend) extend breakeven to 10-12 years
- Premature battery replacement: Replacement after 5-6 years (observed in humid climates) adds R1.5-2 million per bus
- Infrastructure financing costs: Debt servicing for depot upgrades adds R800,000-1.2 million annually
- Opportunity costs: Capital tied up in expensive buses could alternatively fund fleet expansion

Recommendation: Conduct detailed TCO modelling using eThekweni-specific parameters (local electricity rates, observed degradation patterns, actual maintenance costs) rather than relying on manufacturer estimates or international case studies with different contextual assumptions.

4.9.6 Synthesis of Practical Recommendations

In synthesis, these practical findings suggest a cautious, phased, learning-oriented approach to electric bus adoption in eThekweni Municipality, consistent with transition management theory and best practice in technology diffusion (Geels, 2012; Rogers, 2003):

- Prioritize infrastructure upgrades before vehicle procurement to avoid operational bottlenecks
- Begin with 10-15 buses on flat routes, not immediate citywide deployment
- Invest heavily in workforce development (R3.5-4.5 million) as prerequisite for success
- Establish strong OEM partnerships to mitigate technical risks during transition
- Conduct rigorous TCO analysis using local data, not manufacturer claims
- Plan for 8–12-year timeframe to financial breakeven, requiring sustained political and institutional commitment

These practical insights complement the theoretical analysis by translating stakeholder perspectives and empirical evidence into actionable guidance for transport managers and municipal decision-makers (Yin, 2018; Creswell & Poth, 2018).

4.10 Major Theme 2: Financial Sustainability and Investment Viability

4.10.1 Sub Theme 1: Long-term Return on Investment and Cost Recovery

Interview results indicate that stakeholders believe eThekweni's electric bus financial sustainability relies on high upfront costs and complex long-term returns. Focus groups noted that bus acquisition and charging infrastructure expenses are significantly higher than those for diesel fleets. While energy and maintenance savings were acknowledged, battery replacement costs pose challenges. Participants emphasised the importance of comprehensive financial models that consider life-cycle costs, battery deterioration, and fluctuating electricity prices to accurately assess return on investment amidst evolving technology and market conditions.

Participants Responses

“Absolutely—the initial investment is the sticking point for decision-makers. Our financial models show that while operational savings can be realised over time, the upfront spend is a tough sell. We’re piloting blended finance models—mixing public, private, and donor funding, but scale remains a challenge” (Participant 6, Focus Group 1).

“Lifecycle analysis suggests savings are possible, but only if battery management is optimal and electricity costs are kept low. Battery recycling and second-life programmes can help offset replacement costs in the future” (Participant 5, Focus Group 1).

A close examination of electric bus investments underscores the tension between their short-term financial implications and long-term advantages. Stakeholders are drawn to the potential for reduced lifetime costs through savings on fuel and maintenance; however, unforeseen factors can jeopardise financial sustainability. Issues such as unexpected battery replacement costs, fluctuations in electricity prices, and volatile import currency exchange rates can diminish anticipated operational savings. While municipal planners and financial officers view “blended finance models” and “lifecycle analysis” as innovative strategies, the ultimate success of these approaches heavily relies on market conditions and policy incentives.

Research supports the notion that the total cost of ownership (TCO) for electric buses can indeed be lower than that of diesel buses in favourable scenarios, including stable energy pricing, effective battery management, and advantageous financing (Thomson & Webb, 2018). However, in eThekweni, ongoing challenges with battery costs and replacement timelines pose risks to long-term cost recovery (Zhang, Lee & Singh, 2020). Although the economic rationale for electric buses is compelling, the viability of such projects in South Africa remains precarious due to technological, financial, and regulatory uncertainties. Thus, sustained governmental and market support is crucial for achieving long-term returns on investment in electric bus programs.

4.10.2 Sub Theme 2: Complexities in Funding Blends and Capital Sourcing

The interview results indicate that eThekweni faces challenges in securing funds for electric bus procurement and charging infrastructure. Stakeholders view municipal budgets, provincial grants, and donor support as fragmented. Bureaucratic hurdles and lengthy approval processes hinder access to financial resources. Additionally, there is a disconnect between project timelines and funding cycles, along with coordination issues among those advocating for electric transportation.

Participants Responses

“Public-private partnerships are promising, but the private sector wants guarantees on returns. PPP models need to be backed by clear policy signals and risk guarantees. More alignment between municipal, provincial, and national policies would also streamline funding flows” (Participant 6, Focus Group 1).

“Procurement rules are not always fit for innovative projects. Sometimes budget cycles and funding flows aren’t aligned with the project rollout, which leads to under-spending or missed opportunities. Inter-agency issues? There’s some rivalry over who leads what, so, yeah, coordination is a challenge” (Participant 5, Focus Group 2).

The complexities of blended finance schemes highlight significant challenges in financing electric bus transitions. Municipalities face pressures to diversify funding sources to meet substantial cash requirements for electricity. However, this diversification often leads to mismatches in stakeholder risk appetites and financing schedules. Compounding these issues, global climate funding remains slow and inaccessible, making private sector engagement difficult. Current financial and regulatory frameworks do not adequately support the rapid innovations needed for electric bus deployment.

Similar obstacles are noted in academic literature. Anderson and Raskin (2021) and Morris and Sullivan (2018) emphasise that successful global rollouts of electric buses necessitate coordinated, multi-source funding. Unfortunately, institutional misalignment and stringent regulatory structures frequently hinder actual implementation, particularly in emerging economies. Van der Merwe and Van Niekerk (2020) point out that policy fragmentation and the absence of a cohesive investment strategy impede electric mobility progress in South Africa.

The experiences of eThekweni reflect broader trends, underscoring that even promising financial models require policy alignment, clear leadership, and active stakeholder participation to succeed. Ultimately, strategic collaboration and adaptive governance are crucial for making electric bus investments viable, even as funding challenges persist.

4.10.3 Sub Theme 3: Risk Management in Economic Decision-Making

During the eThekweni electric bus deployment, stakeholders emphasised the importance of risk management in economic decision-making. Key concerns included battery longevity, operational expenses, and technical changes. Financial analysts and transportation agencies expressed worries about unpredictable capital costs, such as battery replacements and infrastructure updates. Additionally, the absence of local benchmarks hindered accurate forecasting.

Financial uncertainty stemming from changing regulations and unclear incentives complicates long-term planning, impacting procurement and maintenance budgets. Stakeholders noted a lack of government guarantees and private insurance for e-mobility assets, leading to cautious investment and delayed decisions. Decision-makers require comprehensive scenario analysis and dynamic risk assessment tools before undertaking significant financial commitments.

Participants Responses

“Private financiers focus on long-term returns and risk mitigation, demanding solid guarantees and policy consistency before committing capital” (Participant 6, Focus Group 1).

“Financially, diesel operations have fewer hidden costs. Electric buses have unpredictable costs, mostly related to batteries and charging infrastructure maintenance” (Participant 5, Focus Group 2).

The data indicate a significant perceived risk associated with the transition to electric buses in economic decision-making. Anderson and Raskin (2021) revealed that unanticipated advancements in battery technology have rendered cost estimates by public transport authorities unreliable. Meyer, Hook, and Stone (2016) acknowledged the potential long-term benefits of electric buses but caution that issues related to component durability and infrastructure compatibility necessitate prudent financial planning. This concern aligns with Zhang, Lee, and Singh's (2020) global analysis, which underscores the importance of strong institutional frameworks and risk-sharing mechanisms, such as government-backed guarantees or targeted insurance, to encourage private sector investment.

The literature presents varying perspectives on threat management. Bohnsack, Pinkse, and Kolk (2020) cautioned that overly optimistic projections regarding technology costs could lead to budget overruns if actual market conditions diverge. In contrast, Venter (2021) has advocated for scenario-based financial modelling to enhance investment feasibility. Qualitative interviews with stakeholders in eThekweni reveal a preference for measured, incremental investments instead of swift, large-scale implementations, reflecting a desire for a more cautious approach to adopting electric bus technology.

4.10.4 Sub Theme 4: Incentivisation and Attractiveness for Private Sector Participation

Stakeholders believe current incentives for private electric bus adoption are inadequate and unpredictable. Both focus groups noted that government support measures are complicated and insufficient. Operators and analysts emphasised stronger backing for private electric vehicles. Participants criticised bureaucratic hurdles that limit program accessibility and impact. There is a consensus that limited local content, and industrial incentives hinder domestic development and scalability of electric bus networks. Stakeholders seek proactive and responsive mechanisms to support capital, operations, and workforce development. Public-private collaborations were highlighted, but the private sector remains hesitant due to unpredictability and risk-sharing concerns.

Participants Responses

“PPP models need to be backed by clear policy signals and risk guarantees. More alignment between municipal, provincial, and national policies would also streamline funding flows” (Participant 6, Focus Group 1).

“Support measures could be more proactive. We’re often reacting to new announcements instead of having long-term certainty” (Participant 2, Focus Group 2).

The findings indicate that current incentives are inadequate for the needs of potential participants in the private sector electric bus ecosystem. Nkomo and Fletcher (2021) argued that South Africa's incentive structures fall short of supporting sustainable transport effectively. To enhance private investment and foster industrial innovation, Morris and Sullivan (2018) have advocated for targeted tax credits, grant financing,

and expedited depreciation allowances. Additionally, Anderson and Raskin (2021) have highlighted the importance of robust public-private partnerships and risk-sharing agreements to mitigate financial risks for private entities.

To further support early-stage investments, Hook, Meyer, and Stone (2020) recommend the use of blended finance along with milestone-based subsidies. Venter (2021) suggests that tying incentives to specific socio-economic and environmental outcomes could enhance their effectiveness. Moreover, Thomson and Webb (2018) emphasised that long-term operational subsidies, particularly those aimed at workforce development and local manufacturing, are crucial for driving sectoral growth. Overall, participants express a significant need for both capital and operational funding to advance their initiatives.

4.10.5 Sub Theme 5: Socioeconomic Spillovers from E-mobility Investments

Stakeholder interviews indicate that electric bus investments can drive socioeconomic growth beyond transportation. Participants identified opportunities in charging infrastructure, battery maintenance, and technical support, emphasising the need for skills development in operating advanced electric bus technology. Many believe that localising component production could enhance economic multipliers and community empowerment. However, these benefits rely on intentional policy frameworks to maximise local content and awareness. There are concerns about the equitable distribution of these benefits and whether they will lead to improved public services or lower commuter fees.

Participants Responses

“Economic multipliers are possible if supply chains for components are localised. Communicating these broader benefits through media, town halls, and stakeholder forums is essential” (Participant 5, Focus Group 1).

“If the buses can help create jobs, reduce pollution, and make commuting nicer, it’s good for everyone. I think public campaigns and real-life success stories would help win people over” (Participant 4, Focus Group 1).

Jackson and Young (2019) have highlighted that large-scale e-mobility initiatives can drive local value chain development, enhance labour skills, and empower communities economically. Venter (2021) have underscored the necessity of an integrated

industrial policy and transport strategy in South Africa to ensure equitable access to new job opportunities and improve service quality. Meyer, Hook, and Stone (2016) have further emphasised that localising electric bus supply chains benefits ancillary sectors and fosters regional growth.

However, caution is warranted, as noted by Anderson and Raskin (2021). They argued that without effective skills transfer and inclusive participation, existing industry players or urban elites might disproportionately reap the benefits, exacerbating inequality. Continuous and transparent public communication is essential to garner broad support and maintain the social license necessary for these initiatives.

To maximise the socioeconomic impact of e-mobility investments in eThekweni, intentional and inclusive policy actions, along with active stakeholder engagement and robust monitoring, are vital. The study advocates for e-mobility transitions that prioritise social equity and local capacity-building to ensure truly transformative outcomes.

4.11 Major Theme 3: Transformation of Urban Environmental Quality

4.11.1 Sub Theme 1: Shifts in Public Perception of Environmental Stewardship

Qualitative data indicated that eThekweni electric buses positively influenced community and stakeholder perceptions of environmental stewardship. Participants noted increased awareness of e-mobility's benefits, including improved air quality and reduced diesel emissions. Stakeholders associated the adoption of electric buses with municipal sustainability and civic pride. Many passengers and citizens, previously indifferent to environmental issues, now support clean public transport. However, concerns were raised about the sustainability of electricity sources and battery waste disposal, highlighting the need for transparent environmental management from the municipality.

Participants Responses

“Compared to diesel, the difference in tailpipe emissions is obvious—no smoke, less smell. It makes the city feel cleaner” (Participant 2, Focus Group 1).

“Public campaigns showing these health improvements could help win more support for the project.... “As a commuter, I hope the city has a plan for safe disposal. I’ve read about problems overseas with battery waste” (Participant 4, Focus Group 2).

As low-emission transit gains global prominence, public awareness of environmental issues is increasing, bolstering urban sustainability efforts. Evidence indicates that the adoption of electric buses notably decreases particulate matter and nitrogen oxides (Gupta & Bose, 2020; Stone, 2019). Venter (2021) highlighted that public support for electric transportation grows when individuals observe tangible environmental benefits in their daily lives. However, there is a noted ambivalence regarding concerns about battery disposal and the electricity source, echoing the cautions of Jackson and Young (2019), who emphasised the importance of managing both vehicles and power sources holistically throughout their lifecycle.

While clear environmental improvements can positively influence public perception, the need for comprehensive system management is crucial. Hook, Meyer, and Stone (2020) argued for governance frameworks that are open, participatory, and accountable to foster sustainable urban development. Thus, the success of a municipality’s e-mobility policies will be gauged by both symbolic and substantive

outcomes, necessitating ongoing public engagement and transparent environmental reporting. For a sustained positive public image, municipalities should actively integrate citizen feedback into policy revisions and address concerns related to the lifespan and sourcing of energy, as emphasised in this study.

4.11.2 Sub Theme 2: Holistic Assessment of Health and Community Well-being

Electric buses led to a community health study showing fewer respiratory symptoms among participants, who felt safer and more comfortable using public transit. The quieter and smoother operation of electric buses reduced noise pollution and improved urban living conditions. This shift has made public transport more appealing, potentially enhancing social cohesion and accessibility. However, stakeholders have cautioned that poor battery management could harm the environment, emphasising the need for longitudinal data to connect health trends to electric bus usage.

Participants Responses

“We’ve started to see fewer complaints about air quality, and local clinics report slightly less respiratory distress on main bus routes” (Participant 1, Focus Group 1).
“I’ve noticed less coughing from passengers and myself, especially during rush hour” (Participant 3, Focus Group 2).

“Ongoing health monitoring and environmental sensors should be part of the programme, data transparency builds trust” (Participant 5, Focus Group 1).

The qualitative findings align with previous quantitative studies indicating that the deployment of urban electric buses enhances public health and social well-being. Research by Gupta and Bose (2020) highlighted electric bus adoption in various Asian and African cities leads to decreased local pollution and respiratory ailments. Furthermore, Stone (2019) and Jackson and Young (2019) have argued that quieter and cleaner urban transit systems confer psychological and social benefits, particularly in densely populated regions.

However, some participants emphasised the need for rigorous and transparent monitoring, reflecting scholarly critiques regarding the absence of long-term empirical health data in many e-mobility pilots (Meyer, Hook, & Stone, 2016). Concerns about lifecycle hazards and environmental justice have led to a growing consensus that transformative mobility should be evaluated through a lens of well-being,

encompassing social equity, accessibility, and comprehensive lifecycle accountability (Schäfer, 2019).

In light of these perspectives, eThekweni's policymakers need to establish community-engaged, evidence-based evaluation frameworks that promote sustainable and equitable well-being. This study underscores the importance of integrating technological change and adaptive governance, advocating for holistic and inclusive strategies to reform urban transportation sustainably.

4.11.3 Sub Theme 3: Interaction of E-buses with Broader Sustainable City Initiatives

Interviews reveal that eThekweni residents view electric buses as both an opportunity and a challenge for sustainable municipal operations. Stakeholders emphasised the need for integrated mobility planning and renewable energy. Several noted that deploying electric buses without accompanying sustainable measures is a significant hurdle. Policymakers highlighted a lack of charging infrastructure coordination with urban energy initiatives and bike lanes. Insufficient cross-departmental communication has hindered the alignment of bus timetables with other green mobility options. Analysts warned that without broader investments, the economic and environmental benefits of e-buses could diminish. A comprehensive study indicates that realising the potential of electric buses for a sustainable city requires a coordinated, multi-sectoral approach.

Participants Responses

“Local government should incentivise start-ups and SMEs to enter the supply chain. We could also establish formal partnerships with cities that have successfully scaled electric buses, to share knowledge and avoid reinventing the wheel” (Participant 4, Focus Group 2).

“We’re working with public health agencies to track outcomes and will launch a dashboard for the public to see real-time improvements soon” (Participant 6, Focus Group 1).

These perspectives acknowledge the possibility for e-bus acceptance and sustainability measures to collaborate. Following international best practice, participants sought digital integration platforms for real-time data sharing and

multimodal connectivity. Policy frameworks for transport, energy, and urban planning agency coordination were repeatedly requested. Participants noted successful abroad models but stressed the necessity for local adaptation for relevance and sustainability in South Africa. Electric bus sustainability is highest in areas with complete urban planning that integrate transport electrification (Zhang et al., 2020). Moving forward, eThekweni's e-bus attempts to improve urban environmental quality will work best with citywide sustainability planning.

4.11.4 Sub Theme 4: Visibility and Communication of Environmental Benefits

Effective communication of environmental benefits is essential for gaining public acceptance and political support for electric bus programs. Interview findings revealed that commuters and operational staff noticed improvements like cleaner air, but felt the public was unaware of them. Policymakers emphasised that the positive environmental impacts need clear communication through public campaigns and community feedback. While regular bus passengers recognise benefits like reduced soot and health issues, the general public may not. Interviewees agreed that transparent communication backed by factual evidence is key to sustained public support and policy development.

Participants Responses

“Public campaigns showing these health improvements could help win more support for the project” (Participant 4, Focus Group 1).

“We’re working with public health agencies to track outcomes and will launch a dashboard for the public to see real-time improvements soon” (Participant 6, Focus Group 1).

“Air feels fresher in busy areas, and public feedback is mostly positive. We need more data, but the signs are there” (Participant 2, Focus Group 1).

The excerpts highlight that the communication of environmental benefits is often inadequate. While dashboards and sensors can enhance transparency and facilitate evidence-based advocacy, research indicates that merely increasing visibility is not enough; participatory systems for public engagement and feedback are essential. To effectively promote low-carbon transport initiatives, such as e-bus programs in

eThekwini, a thoughtful and interactive communication strategy is necessary to validate and broaden stakeholder support.

4.11.5 Sub Theme 5: Challenges of Achieving True Zero-Emission Mobility in the Local Context

Interview findings indicate that participants recognise the challenges of achieving zero-emission mobility with electric buses in South Africa. A major concern is the reliance on a coal-heavy energy grid, limiting the environmental benefits of e-buses. Stakeholders, particularly energy experts and policymakers, emphasised that fleet electrification alone cannot decarbonise public transport without a shift towards renewable energy. Concerns also arose over battery production, end-of-life management, and the lack of local recycling facilities. Some participants called for stronger policies to address these issues, while others advocated for partnerships with manufacturers to promote extended producer responsibility and technological innovation.

Participants Responses

“The coal-heavy grid limits the full potential for emissions reduction, but as the grid becomes greener, benefits will increase” (Participant 1, Focus Group 1).

“Lifecycle analysis is vital. Partnerships with manufacturers for take-back schemes, and strong regulation, are the way forward” (Participant 5, Focus Group 1).

A critical analysis of the extracts reveals that participants grasp the complex challenges of achieving zero emissions. The findings align with existing academic literature, highlighting that vehicle electrification, renewable energy generation, and life-cycle governance are essential for decarbonising urban mobility (Brooks & Goss, 2018; Schäfer, 2019; Nkomo & Fletcher, 2021). However, local issues, such as insufficient recycling infrastructure and legislative deficiencies, present significant barriers. This study builds upon previous research by advocating for systemic solutions tailored to the unique capacities and resources of local contexts. To realise zero-emission mobility in eThekwini, it is crucial to foster cross-sector collaboration, commit to long-term policies, and support local green technology enterprises.

4.12 Major Theme 4: Policy Innovation and Collaborative Governance

4.12.1 Sub Theme 1: Multi-level Policy Alignment and Strategic Cohesion

The focus group data indicate that misalignment among local, provincial, and national policies hinders electric bus adoption in eThekweni. Participants cited fragmented responsibilities, inter-agency rivalry, and unclear e-mobility leadership as factors that slow project development and financing. They pointed out that transport, environmental, and procurement rules are insufficiently linked to enable a systemic shift toward electric bus adoption. Although national climate targets exist, local implementation suffers from unclear directions, funding, and collaboration issues. Governance challenges have led to delays, missed funding opportunities, and difficulties in scaling pilot initiatives to city-wide deployment.

Participants Responses

“We need streamlined, dedicated green procurement processes and clearer inter-agency communication channels” (Participant 5, Focus Group 1).

“A centralised task force with cross-agency representation could speed up decision-making and ensure everyone’s on the same page” (Participant 6, Focus Group 1).

The analysis of participant responses reveals a consensus that multi-level policy misalignment significantly hinders the scaling of electric buses. Many participants noted that the absence of coordinated strategies across government levels leads to operational inefficiencies and diminished accountability. Proposed solutions include forming cross-sectoral task teams, synchronising policy cycles, and enhancing stakeholder engagement to align environmental, transportation, and economic policies.

When juxtaposed with existing literature, these insights find support. Nkomo and Fletcher (2021) highlighted that fragmented policy frameworks obstruct the adoption of renewable transit solutions in South Africa, while Van der Merwe and Van Niekerk (2020) stress the need for integrating national and local policies for sustainable transportation. Similarly, research by Zhang, Lee, and Singh (2020) have indicated that cities with robust multi-level governance systems foster e-mobility more

effectively. However, Bohnsack, Pinkse, and Kolk (2020) cautioned that centralisation may stifle local innovation unless balanced with meaningful local input.

Overall, these findings align with the literature, underscoring the importance of policy cohesiveness for successful electric bus integration. They also prompt a call for targeted institutional transformation within eThekweni to facilitate significant advancements in its electric bus program. This study suggests that achieving the full potential of this program will require deliberate multi-level policy synchronisation founded on collaborative governance.

4.12.2 Sub Theme 2: Streamlining of Regulatory Pathways for Technology Adoption

Participants believe the regulatory environment for breakthrough technologies like electric buses is cumbersome and misaligned with their needs. Focus groups noted that delayed procurement, outdated standards, and regulatory ambiguity cause significant delays, particularly in obtaining licenses, route permissions, and technical certifications. The burden on operators is heightened by a lack of incentives for public transport electrification, as support often favours private cars. These regulatory delays have led to missed funding opportunities, underutilised buses, and increased project risks, deterring investment.

Participants Responses

“Incentives exist but are often too small or hard to access. Red tape is a real problem” (Participant 1, Focus Group 1).

“The technical criteria for eligibility are often out of date. They should be revised as technologies evolve. Faster, simpler, and more accessible processes would help more stakeholders benefit” (Participant 6, Focus Group 1).

The challenges posed by regulatory complexity and inertia present significant barriers to the adoption of public transport systems. Participants highlighted the need for adaptive regulatory frameworks that facilitate the testing of new technologies, streamline approval processes, and accommodate evolving technical standards. Thomson and Webb (2018) have pointed out that regulatory sandboxes and fast-track pathways can accelerate the deployment of electric buses internationally. Meanwhile,

Anderson and Raskin (2021) emphasised that incentives should be clear, substantial, and easily accessible to encourage adoption.

In South Africa, experts such as Nkomo and Fletcher (2021) have identified pervasive regulatory obstacles that call for policy learning and iterative improvement. Morris and Sullivan (2018) cautioned against hasty deregulation, which could compromise quality and safety, underscoring the necessity for a balanced approach. Insights from local interviews, coupled with global research, indicate that eThekweni's efforts to innovate with electric buses will hinge on its capacity to craft a clear, flexible, and responsive regulatory framework. Ultimately, the municipality's success in technology adoption will rely on its ability to modernise regulations, build public administration capacity, and engage stakeholders effectively.

4.12.3 Sub Theme 3: Empowerment and Engagement of Local Stakeholders

Focus group interviews revealed both challenges and opportunities for stakeholder engagement in eThekweni's electric bus transition. Participants encouraged involvement from drivers, maintenance workers, and community members, but noted that top-down decisions did not allow for sufficient bottom-up feedback, limiting policy revisions. Many felt that local skills development lacked structure and accessibility, hindering capacity-building. Concerns were raised about inconsistent education on electric bus benefits and risks, which alienated stakeholders. Additionally, high-level decisions often ignore local needs like employment stability and service reliability, undermining trust and community support.

Participants Responses

“Communities should understand the benefits and have a say in implementation, especially if routes or services are changing. Policy should also address skills development and retraining for existing workers” (Participant 3, Focus Group 2).

“Outreach and education are important. Communities should understand the benefits and have a say in implementation, especially if routes or services are changing” (Participant 3, Focus Group 2).

The findings underscore the critical role of participatory techniques in adopting sustainable urban transport innovations, echoing research from both global and South

African contexts (Nkomo & Fletcher, 2021). Venter (2021) have argued that engaging diverse stakeholder perspectives fosters equity and operational sustainability, whereas top-down approaches often overlook local knowledge and interests. Research by Zhang et al. (2020) revealed that cities promoting community involvement in electric mobility transitions enjoy stronger long-term public support and cohesive policy frameworks.

Conversely, Hook et al. (2020) highlighted issues such as bureaucratic inertia and fragmented communication, which undermine these participatory ideals. This sentiment is echoed by survey respondents who reported information gaps and procedural inefficiencies. Furthermore, Nkomo and Fletcher (2021) stressed that empowerment must extend beyond mere information sharing to encompass tangible resources for skill development, an essential aspect highlighted by participants in eThekwini's focus groups.

As such, while the literature advocates for robust stakeholder participation, the evidence shows a disconnect in eThekwini's implementation. This discrepancy points to an urgent need for more structured, inclusive, and ongoing engagement frameworks. Ultimately, the transition to electric buses will only achieve sustainability and public legitimacy through the active empowerment and engagement of all local stakeholders.

4.12.4 Sub Theme 4: Institutional Memory and Knowledge Sharing Mechanisms

Both focus groups highlighted the absence of effective procedures for storing and sharing institutional knowledge on electric bus installations. Interviewees pointed to issues like worker turnover, ad hoc training, and a lack of established knowledge repositories. Technical expertise and insights were often siloed within departments or lost with staff departures. Inadequate post-project debriefs, and documentation led to recurring mistakes. Respondents emphasised the need for integrated seminars and reports to enhance organisational learning, as well as digital and face-to-face platforms for knowledge sharing, succession planning, and innovation.

Participants Responses

“There’s a need for standardised protocols and better tracking software for maintenance schedules and inventory. If we could build partnerships with local

colleges or universities, maybe we could develop a pipeline for specialised technical staff” (Participant 6, Focus Group 2).

“Some of our best lessons get lost when people move to new roles. We need a better way to capture what works and what doesn’t” (Participant 4, Focus Group 1).

The findings underscore the importance of institutional memory and effective information sharing in fostering adaptive governance of urban transport innovations (Reyes et al., 2021). Braun and Clarke (2006) have advocated for thematic analysis and documentation to support organisational learning. Reyes et al. (2021) highlighted that inadequate recordkeeping, or the absence of 'living codebooks', can lead to repetitive errors and hinder innovation cycles, contributing to participant frustration over lost knowledge. Additionally, Bell et al. (2022) have demonstrated that embedding knowledge management in organisational practices enhances adaptation to technological changes.

However, isolated approaches can be counterproductive, as noted in feedback from eThekweni's stakeholders. Further research indicates that regular debriefs, peer learning sessions, and digital repositories can alleviate these issues (Naeem et al., 2024). Overall, the evidence reinforces that strengthening knowledge sharing is vital for achieving resilient and cost-effective transformations in public transport technology. Addressing gaps in institutional memory in eThekweni will be essential for ensuring sustainable advancements and continuity during implementation.

4.12.5 Sub Theme 5: Cross-sectoral Partnerships for Future-proofing Public Transport

A common theme in the interviews was the need for strong cross-sector partnerships to ensure the durability of eThekweni's public transport network during the electric bus transition. Participants mentioned promising collaborations with local universities, energy utilities, tech firms, and international donors. However, these partnerships were often project-specific and reliant on personal networks, lacking the necessary coherence for long-term impact. There was a consensus that scaling electric mobility requires formalised, flexible partnerships involving government, academia, the private sector, and civil society. Challenges included bureaucratic bottlenecks, unclear roles, and a lack of shared success metrics. Many interviewees highlighted the potential to

use global experiences, particularly from cities like Shenzhen and Santiago, while adapting strategies to local conditions.

Participants Responses

“Learning from cities like Santiago and Shenzhen, strategic international partnerships can bring both capital and expertise” (Participant 2, Focus Group 2).
“Public-private partnerships could speed up infrastructure development. Maybe offer incentives for local tech companies to enter the market” (Participant 5, Focus Group 2).

“Cross-sector steering committees for each major project. Community involvement can be strengthened through regular public forums” (Participant 2, Focus Group 2).

The interview findings align with a growing body of research underscoring the necessity of cross-sectoral collaboration for achieving urban transport electrification (Zhang et al., 2020). Anderson and Raskin (2021) have illustrated how integrated public-private-academic partnerships have enabled cities to overcome barriers to electric bus deployment, including financial, informational, and infrastructural challenges. Zhang et al. (2020) further argued that adaptive, forward-thinking public transport systems necessitate ongoing collaboration and international knowledge exchange.

However, Bohnsack et al. (2020) cautioned that these collaborations must be managed strategically, as competing interests and regulatory uncertainties can hinder their effectiveness, a challenge reflected in the participants’ experiences of ad hoc collaboration and bureaucratic inertia in eThekwini. Additionally, Morris and Sullivan (2018) have identified cross-sector financing options and innovation hubs as valuable mechanisms for fostering resilience and enhancing local capacity.

The current findings not only confirm previous research but also highlight the critical need for consolidating and institutionalising cross-sector collaborations in eThekwini. This shift is essential for future-proofing public transit, scaling innovation, and aligning local practices with global standards. The analysis emphasises the importance of moving from opportunistic partnerships to deeply rooted, strategic frameworks, which

are vital for making electric transportation both sustainable and transformative in the local context.

4.13 Observations

4.13.1 Technical and Operational Performance across Varied Urban Contexts

In the eThekweni Municipality, the performance of electric buses is significantly influenced by terrain, climate, and route characteristics. Electric buses operating in flat suburban and urban areas demonstrated robust battery performance, maintaining a state-of-charge above 40% during continuous use. However, those deployed on challenging topographical routes, such as KwaMashu and Ntuzuma, faced substantial energy consumption issues. Operational logs indicated frequent "low battery" warnings and unscheduled mid-route recharges, highlighting the difficulties of steep gradients on battery systems. Anderson and Raskin (2021) have acknowledged that these factors strain electric bus performance in diverse urban environments.

Weather conditions also posed operational challenges, particularly during wet or early morning shifts. Instances of condensation affected door sensors, leading to manual resets or emergency overrides. High humidity and cold temperatures exacerbated software malfunctions in door and dashboard systems, often necessitating immediate technical support. This aligns with findings from Zhang, Lee, and Singh (2020) and Bohnsack, Pinkse, and Kolk (2020), who argued that environmental and infrastructural factors critically impact the reliability of electric bus technology.

Furthermore, the charging infrastructure in eThekweni is insufficient, particularly in rural and peri-urban areas, where a lack of charging stations compromises service reliability and turnaround times. Despite these technical limitations, operational teams have shown adaptability and responsiveness. The implementation of mobile toolkits and real-time reporting systems has enabled maintenance staff to quickly diagnose issues and minimise service interruptions. As noted by Bell et al. (2022), proactive problem-solving is a key aspect of best practices, underscoring the importance of ongoing training and institutional learning for system resilience. While eThekweni's electric buses display potential for development and adjustment, persistent technical

challenges, especially in difficult terrains and adverse weather, underscore the necessity for targeted investments in both hardware and human resources.

4.13.2 Economic Considerations and Emerging Cost Structures

Adopting electric buses in eThekweni faces challenges related to initial investments and ongoing costs. Despite lower fuel and traditional maintenance expenses, battery diagnostics, electronic systems, and personnel training have increased significantly. Battery management and electronic component replacement emerge as key recurring costs, supporting the "front-loaded" cost structure described by Anderson and Raskin (2021) and Zhang et al. (2020).

Electricity costs vary due to time-of-day charging; night charging is often cheaper than diesel refuelling, while peak or emergency charging can escalate costs and disrupt grid stability, leading to delays. Meyer, Hook, and Stone (2016) emphasised the importance of efficient charging cycles for cost savings in electric public transport.

The town has also formed partnerships with industries and educational institutions to diversify revenue. Effective cashless payment systems and student transport subsidies have reduced administrative costs, aligning with Morris and Sullivan's (2018) view on innovative financial strategies for sustainable urban mobility. However, challenges like fare reconciliation in remote areas complicate the economics.

While operational innovations may enhance the profitability of eThekweni's electric bus program, technical challenges and uneven infrastructure development remain critical issues to address.

4.13.3 Environmental Impacts: Air Quality, Noise, and Waste Management

Observational data show that transitioning to electric buses has significantly improved air quality and reduced noise pollution. Commuters and staff at busy locations, like the Durban North Gateway and the central university hub, have noted the absence of diesel fumes and lower particulate pollution. These observations align with Gupta and Bose (2020) and Stone (2019), who documented substantial decreases in airborne pollutants and noise in cities with large-scale electric bus implementation. Air quality sensors confirm lower NO_x and PM_{2.5} concentrations during operational hours compared to pre-electrification levels.

However, environmental challenges have emerged, particularly regarding battery and electronic waste management. Obsolete battery modules and malfunctioning components are being stored at various depots, raising concerns among staff about the lack of formal disposal guidelines. This issue, highlighted by Brooks and Goss (2018), points to the need for balancing the sustainability of electric mobility with the lifecycle impacts of lithium-ion batteries. Additionally, recycling efforts at major hubs are inconsistent, revealing a gap between policy and commuter behaviour that must be addressed to enhance the overall sustainability of electric bus systems.

4.13.4 Policy and Regulatory Issues: Compliance, Communication, and Public Engagement

Integrating electric buses into eThekweni's public transport system required legislative and regulatory reforms, yielding both benefits and challenges. Key transit hubs were enhanced with bilingual safety signage, emergency protocols, and compliance audits, improving regulatory engagement and commuter transparency through real-time information boards in English and isiZulu.

However, policy gaps remained, especially in rural and industrial areas. The lack of municipal regulations for charging during system stress exposed services to disruptions from load-shedding and grid instability. As noted by Venter (2021), effective feedback mechanisms are vital for ensuring equity in urban transport systems, yet many depots struggled with such systems, complicating the resolution of user issues.

Urban operations thrived under regulatory oversight and modern reporting systems, whereas rural services often relied on informal solutions. The municipality's adaptability was evident in its management of special events using interim waivers and responsive protocols (Nkomo & Fletcher, 2021).

To strengthen regulation, standardise hazardous waste management, focus on rural needs, and broaden digital engagement are critical. These findings highlight the necessity for collaboration among legislators, operators, and the public to reconcile innovation with regulatory frameworks in sustainable mobility.

4.13.5 Accessibility, Equity, and Stakeholder Engagement

This study examines eThekweni's public transit system, highlighting improvements in accessibility and equity for disabled, elderly, and family passengers through features like ramps and priority seating. While drivers and marshals assist commuters, and feedback platforms encourage community engagement, challenges remain, especially in peri-urban and industrial areas where inadequate infrastructure persists. Issues such as rough terrain and insufficient charging stations hinder access for electric bus riders.

The lack of community liaison officers further exacerbates communication gaps between commuters and municipal officials (Nkomo & Fletcher, 2021). Nevertheless, initiatives like flexible scheduling and priority boarding for shift workers show a commitment to equity. The municipality's responsiveness to community feedback in adjusting timetables underscores a move toward participatory governance. Ultimately, achieving meaningful equity and accessibility requires political commitment, infrastructure investment, and systematic public involvement (Venter, 2021), with the urban-peri-urban divide posing a significant challenge.

4.13.6 Thematic Synthesis and Methodological Reflections

The field study indicates that eThekweni's public transit has improved accessibility and equity, benefiting disabled, elderly, and family passengers through features like ramps and priority seating at key hubs. Support from drivers and platform marshals, along with community feedback kiosks, further enhances the experience.

However, challenges persist, particularly in peri-urban and industrial areas where poor infrastructure limits accessibility for vulnerable electric bus riders. Limited stakeholder engagement and communication gaps between commuters and officials exacerbate these issues (Nkomo & Fletcher, 2021).

Efforts such as flexible scheduling and priority boarding have been implemented to support shift workers, students, and low-income families. The municipality's responsiveness to community input demonstrates a commitment to participatory governance. Ultimately, achieving genuine equity requires political will, infrastructural investment, and an inclusive approach beyond technical solutions (Venter, 2021). Addressing the urban-peri-urban divide remains a key challenge.

4.14 Chapter Summary

This chapter has presented the findings from qualitative analysis of data collected through semi-structured interviews, focus groups, document analysis, and field observations. Four major themes emerged, addressing the technical, economic, environmental, and policy dimensions of electric bus adoption in eThekweni Municipality.

Theme 1 (Technical Challenges) revealed that battery performance degradation under eThekweni's humid, hilly conditions, inadequate charging infrastructure, and limited maintenance capacity represent significant operational barriers (Gupta & Bose, 2020; Nkomo & Fletcher, 2021). Theme 2 (Economic Implications) demonstrated that while high capital costs deter adoption, long-term operational savings and potential economic opportunities provide partial justification (Anderson & Raskin, 2021; Mottschall et al., 2019). Theme 3 (Environmental Impact) showed that environmental benefits are real but moderated by South Africa's coal-dependent grid (Harris & Thompson, 2020; Stone, 2019). Theme 4 (Policy and Governance) emphasized that fragmented policy frameworks and limited inter-agency coordination hinder adoption (Nkomo & Fletcher, 2021; Bohnsack et al., 2020).

All findings were presented with verbatim participant quotations (italicized and attributed), field observations (labelled and distinguished), documentary evidence, and continuous triangulation with existing literature, enhancing credibility and demonstrating analytical rigor. The dedicated Practical Findings section (4.9) distilled operational and managerial implications, providing actionable guidance for eThekweni Municipality and Go Durban decision-makers.

Chapter 5 builds on these findings by drawing conclusions aligned with research objectives, articulating the study's contribution to knowledge, and presenting comprehensive recommendations for stakeholders involved in electric bus adoption in South African municipalities.

CHAPTER 5: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter synthesizes the study's findings, draws conclusions aligned with the research objectives, articulates the contribution to the body of knowledge, and presents comprehensive recommendations for stakeholders involved in electric bus adoption in eThekweni Municipality and similar South African urban contexts. The chapter is structured as follows: Section 5.2 explicitly articulates the study's original contribution to academic knowledge. Section 5.3 summarizes key findings from the literature review and empirical investigation. Section 5.4 presents conclusions organized by research objective. Section 5.5 details practical implications for multiple stakeholder groups. Section 5.6 elaborates managerial implications with specific actionable recommendations. Section 5.7 presents structured recommendations across technical, economic, environmental, policy, and social domains. Section 5.8 acknowledges study limitations. Section 5.9 suggests directions for future research. Section 5.10 provides a concluding statement.

5.2 Contribution to the Body of Knowledge

This study makes several original and substantive contributions to the academic literature on sustainable urban transport, technology adoption in developing economies, and electric mobility in African contexts. The contributions extend, refine, and in some cases challenge existing theory and empirical understanding. Four primary knowledge contributions are identified:

5.2.1 Extension of Technology Adoption Theory to Public Transport Infrastructure in Developing Economies

This study extends the Technology Acceptance Model (TAM) and Diffusion of Innovations (DOI) theory to a previously under-examined context: large-scale public transport infrastructure adoption in a resource-constrained Global South municipality. While TAM (Davis, 1989) and DOI (Rogers, 2003) have been extensively applied to

individual technology adoption (smartphones, e-learning platforms, personal vehicles) and private sector innovations, their application to capital-intensive, publicly governed transport systems in developing economies represents a theoretical advancement.

The findings demonstrate that in this context, perceived usefulness and perceived ease of use—TAM's core constructs—are not solely functions of technology characteristics but are fundamentally mediated by infrastructural readiness and institutional capacity. Specifically:

- Perceived usefulness of electric buses is heavily moderated by grid reliability (load-shedding), electricity generation sources (coal vs. renewable), and budgetary capacity—factors under-theorized in original TAM formulations which assumed stable technological environments.
- Perceived ease of use is mediated by local technical expertise availability, manufacturer support accessibility, and compatibility with existing operational protocols—factors more salient in developing economy contexts than in high-income settings where TAM was originally validated.
- The mediating effect of contextual moderators (topography, climate, institutional capacity) is stronger than in original TAM applications, suggesting that technology adoption in infrastructure-dependent sectors requires context-augmented versions of TAM rather than direct application of standard models.

Similarly, the study refines DOI theory by demonstrating that in public transport contexts, compatibility is not merely technical fit but encompasses institutional, financial, and socio-political dimensions. The findings show that trialability—the ability to experiment with innovations on a limited basis—is constrained by capital intensity and public accountability requirements in ways not captured by Rogers' (2003) original formulation based primarily on agricultural and consumer product diffusion.

These theoretical extensions contribute to the growing literature on context-specific technology adoption theories and challenge the assumption that theories developed in high-income, market-driven contexts transfer seamlessly to public sector infrastructure decisions in developing economies (Avgerou, 2008; Walsham, 2017).

5.2.2 Challenge to Universal Environmental Benefits Assumptions

This study provides empirical evidence that challenges a prevalent assumption in electric mobility literature: that electric buses universally deliver substantial environmental benefits. The research demonstrates that in coal-dependent energy contexts like South Africa, where approximately 80% of electricity is coal-generated, the net lifecycle emissions reduction from electric buses is significantly attenuated—estimated at only 20-30% compared to diesel buses, rather than the 70-80% reductions commonly cited in renewable energy contexts.

This finding makes three important contributions:

- It empirically validates lifecycle assessment studies (Harris & Thompson, 2020; Stone, 2019) suggesting that grid composition fundamentally mediates environmental benefits but extends this by documenting stakeholder awareness and interpretation of this limitation—a socio-political dimension absent from technical lifecycle studies.
- It challenges policy narratives that promote electric buses as universally 'green' solutions, demonstrating that without parallel grid decarbonization, electric buses represent incremental rather than transformational environmental improvements. This contributes critical nuance to sustainable transport discourse in developing economies.
- It provides empirical support for integrated energy-transport planning frameworks, demonstrating that effective climate mitigation requires coordinated transitions across sectors rather than siloed technological substitutions.

This contribution is particularly significant for African transport scholarship, where limited research exists on the interaction between energy transitions and transport electrification (Nkomo & Fletcher, 2021). The study provides empirical grounding for policy arguments that transport electrification must be coupled with renewable energy expansion to achieve meaningful emissions reductions.

5.2.3 Empirical Evidence on Climate and Topography Effects Beyond Temperate Contexts

The study provides novel empirical evidence on electric bus battery performance under humid subtropical conditions combined with hilly topography—a climatic and geographical configuration under-represented in existing literature. Most electric bus research focuses on temperate, relatively flat contexts (Northern European cities, Chinese megacities with extensive flat areas) or examines extreme heat (Middle Eastern contexts) or extreme cold (Scandinavian cities) separately.

The findings document that:

- Battery degradation rates in eThekweni's humid coastal climate are 15-20% higher than manufacturer specifications based on temperate testing conditions, primarily due to moisture infiltration, corrosion of internal battery components, and thermal stress from sustained high temperatures (25-35°C year-round).
- Hilly topography (gradients >5%, common in eThekweni) reduces effective operational range by 25-30% compared to flat terrain, with range reduction exacerbated during peak hours when buses are fully loaded. This is more severe than the 15-20% range reduction documented in temperate hilly cities (San Francisco, Zurich) due to combined heat and gradient effects.
- The interaction between humidity, temperature, and topography creates compounding negative effects on battery performance that exceed the additive effects of each factor independently—a finding not predicted by existing literature which typically examines factors in isolation.

These empirical contributions fill a significant geographical knowledge gap in electric mobility literature. The findings have practical implications for other coastal Global South cities with similar climates (Mumbai, Lagos, Rio de Janeiro) and advance understanding of how local environmental conditions mediate electric vehicle performance in ways that generic technical specifications fail to capture.

5.2.4 Comprehensive Multi-Stakeholder Analysis in South African Municipal Context

This dissertation provides one of the first comprehensive, multi-stakeholder qualitative analyses of electric bus feasibility in a South African municipality. While quantitative techno-economic models of electric bus adoption exist (focused on costs, emissions, energy consumption), and policy analyses examine regulatory frameworks, integrated qualitative studies examining technical, economic, environmental, and policy dimensions simultaneously from diverse stakeholder perspectives are rare—particularly in African contexts.

The multi-stakeholder approach yields three methodological and empirical contributions:

- It reveals divergent constructions of 'feasibility' across stakeholder groups. Transport officials emphasize policy alignment and budgetary constraints, fleet managers prioritize operational reliability and maintenance capacity, policy experts focus on climate commitments and international benchmarking, while commuters prioritize affordability and service continuity. These divergent rationalities are obscured in single-perspective studies.
- It identifies implementation gaps between policy intentions (municipal sustainability commitments, national climate targets) and operational realities (budget limitations, technical capacity constraints, infrastructure deficits). Multi-stakeholder analysis reveals that policy-implementation disconnects are not merely communication failures but reflect structural resource and capacity constraints.
- It demonstrates that successful technology adoption in public transport requires not only technical viability and economic feasibility but also social acceptance, institutional readiness, and political commitment—dimensions integrated through multi-stakeholder inquiry but fragmented in single-method studies.

This holistic, multi-perspective approach contributes to qualitative transport research methodology by demonstrating the value of integrative case study designs that bridge technical, economic, social, and political dimensions of transport transitions (Schwanen, 2016).

5.2.5 Synthesis: Advancing Knowledge on Sustainable Mobility Transitions in the Global South

Collectively, these contributions advance understanding of sustainable mobility transitions in resource-constrained urban contexts. The study demonstrates that electric bus adoption in developing economies is not simply a matter of technological transfer from high-income contexts but requires:

- Context-adapted technology adoption theories that account for infrastructure deficits, institutional capacity constraints, and resource limitations
- Integrated energy-transport planning frameworks that recognize grid composition as fundamental to environmental outcomes
- Climate and geography-specific technical assessments that move beyond manufacturer specifications to local empirical validation
- Multi-stakeholder governance approaches that reconcile diverse rationalities and navigate implementation gaps

By providing empirical depth, theoretical refinement, and methodological integration, this study makes an original contribution to the academic literature on sustainable urban transport in the Global South, electric mobility adoption in developing economies, and technology transitions in resource-constrained public sectors. The findings have applicability beyond eThekweni to similar urban contexts across sub-Saharan Africa, South Asia, and Latin America facing comparable challenges in sustainable transport transitions.

5.3 Summary of Findings

5.3.1 Findings from the Literature Review

The literature review (Chapter 2) established that electric bus adoption in developing urban contexts presents multidimensional opportunities and challenges. Technically, success depends on climate adaptation, infrastructure development, and maintenance capacity. Economically, high capital costs create barriers, yet long-term operational savings and innovative financing mechanisms offer viability pathways. Environmentally, benefits are contingent on electricity generation sources,

necessitating integrated energy-transport planning. Policy-wise, comprehensive multi-level governance frameworks are essential.

The review identified significant knowledge gaps regarding electric bus performance in humid subtropical climates, municipal financial capacity in developing economies, stakeholder perceptions in South African institutional contexts, and practical implementation pathways. The integrated conceptual framework synthesized TAM and DOI theory with context-specific moderating factors to guide empirical investigation.

5.3.2 Findings from the Empirical Study

The empirical investigation (Chapter 4) revealed four major themes:

Technical Challenges (Theme 1):

Battery performance degradation under eThekweni's humid, hilly conditions (15-25% below manufacturer specifications), inadequate and unreliable charging infrastructure, load-shedding vulnerabilities, limited local technical expertise, and maintenance capacity constraints emerged as significant operational barriers. However, technological innovations (route optimization, opportunity charging, battery thermal management) and adaptive strategies offer mitigation potential.

Economic Implications (Theme 2):

High capital costs (R4-6 million per electric bus vs. R2-3 million per diesel bus) deter adoption, particularly under municipal budgetary constraints. However, long-term operational cost savings (60-70% lower energy costs, 40% reduced maintenance), employment opportunities in green sectors, and potential for innovative financing (green bonds, PPPs, climate finance) provide partial economic justification. Total cost of ownership breakeven estimated at 8-12 years under eThekweni-specific conditions.

Environmental Impact (Theme 3):

Electric buses eliminate tailpipe emissions, improving local air quality and reducing noise pollution. However, South Africa's coal-dependent grid (80% coal-generated

electricity) attenuates lifecycle emissions reductions to 20-30% compared to diesel buses. Public health benefits (reduced respiratory illnesses) are significant but moderated by upstream power generation emissions. Integration with renewable energy expansion is essential to maximize climate benefits.

Policy and Governance (Theme 4):

Fragmented policy frameworks limited inter-agency coordination, unclear regulatory pathways, insufficient financial incentives, and capacity constraints hinder adoption. Successful implementation requires multi-level policy alignment (national-provincial-municipal), streamlined procurement processes, dedicated funding mechanisms, technical standards development, and strengthened stakeholder engagement.

The dedicated Practical Findings section (Chapter 4.9) distilled operational insights: infrastructure requires R24-36 million electrical capacity upgrades; workforce development needs R3.5-4.5 million training investment; phased procurement recommended (10-15 buses initially); OEM partnerships essential during 3–5-year transition; and rigorous local TCO modelling necessary for financial planning.

5.4 Conclusions Aligned with Research Objectives

This section presents conclusions organized by the four research objectives, grounded in the integrated conceptual framework (TAM/DOI theory + context-specific factors) and supported by empirical evidence.

5.4.1 Objective 1: Technical Feasibility of Electric Buses in eThekweni Municipality

Objective 1: To analyze the technical challenges and operational performance of electric buses under eThekweni Municipality's climatic and topographical conditions.

Conclusion:

Electric buses are technically feasible in eThekweni Municipality, but performance is significantly constrained by local climatic (humid subtropical) and topographical (hilly terrain) conditions. Battery efficiency, range, and lifespan are 15-30% below manufacturer specifications tested in temperate, flat environments. Technical feasibility depends critically on:

- Selection of climate-adapted electric bus models with advanced thermal management systems and oversized battery capacity to compensate for degradation
- Strategic route prioritization, beginning with flat coastal routes and deferring hilly routes until technology matures or opportunity charging infrastructure is established
- Substantial charging infrastructure investment (R24-36 million for three depots) with backup power systems to mitigate load-shedding impacts
- Comprehensive workforce development (R3.5-4.5 million, 3–6-month lead time) to develop high-voltage maintenance expertise
- OEM technical support partnerships to address capacity gaps during the 3–5-year learning curve period

The conclusion aligns with TAM's perceived ease of use construct: technical feasibility exists but requires substantial adaptive measures to achieve user-friendly operations. The findings support DOI theory's complexity attribute: electric buses are perceived as complex innovations requiring specialized expertise, infrastructure, and operational modifications.

5.4.2 Objective 2: Economic Viability of Electric Bus Adoption

Objective 2: To evaluate the economic implications, including cost-benefit analysis, of adopting electric buses compared to traditional diesel buses.

Conclusion:

Electric buses are economically viable over extended timeframes (8-12 years to breakeven) but face significant upfront capital barriers (100-150% cost premium over diesel). Economic viability requires:

- Access to concessional financing, grants, or subsidies covering 30-50% of capital costs to overcome budgetary constraints
- Realistic total cost of ownership modeling using eThekweni-specific parameters (local electricity rates, observed degradation patterns, actual maintenance costs) rather than manufacturer claims
- Phased procurement strategy (10-15 buses initially) to manage financial risk and demonstrate operational viability before large-scale investment
- Long-term political and institutional commitment (10+ years) to sustain investment through electoral and budget cycles
- Integration of co-benefits (air quality improvements, public health gains, job creation, climate leadership) into economic justification beyond narrow TCO calculations

The conclusion aligns with TAM's perceived usefulness construct: while long-term economic benefits exist, high upfront costs and financial uncertainties reduce perceived usefulness among budget-constrained decision-makers. DOI's relative advantage attribute is partially supported: electric buses demonstrate operational cost advantages but not sufficient capital cost advantages to drive rapid adoption without policy intervention.

5.4.3 Objective 3: Environmental and Social Impact Assessment

Objective 3: To examine the environmental impacts of transitioning to electric buses, focusing on reductions in carbon emissions and improvements in urban air quality.

Conclusion:

Electric buses deliver meaningful local air quality improvements and public health benefits by eliminating tailpipe emissions (30-50% reduction in NO_x and PM_{2.5} along major corridors). However, climate change mitigation benefits are substantially attenuated by South Africa's coal-dependent electricity grid, yielding only 20-30% lifecycle GHG reductions compared to diesel buses. Maximizing environmental benefits requires:

- Parallel investment in renewable energy generation (solar, wind) to power charging infrastructure, moving toward 70-80% GHG reductions achievable with green electricity
- Prioritization of electric bus deployment on routes serving low-income communities disproportionately exposed to diesel emissions, advancing environmental justice objectives
- Comprehensive lifecycle planning including battery recycling infrastructure and extended producer responsibility schemes to address end-of-life environmental burdens
- Integration with broader sustainable city initiatives (green buildings, renewable energy, circular economy) to create synergistic environmental benefits
- Transparent communication of both achievements (local air quality) and limitations (upstream emissions) to maintain public trust and manage expectations

The conclusion reveals complexity in DOI's relative advantage attribute: electric buses demonstrate clear environmental advantages locally but contested advantages systemically. TAM's perceived usefulness is moderated by stakeholder environmental values—those prioritizing immediate health benefits perceive high usefulness, while those emphasizing climate mitigation perceive limited usefulness absent grid decarbonization.

5.4.4 Objective 4: Policy and Institutional Requirements

Objective 4: To explore the policy and regulatory requirements needed to support the integration of electric buses into the existing transport infrastructure.

Conclusion:

Current policy and regulatory frameworks are insufficient to enable large-scale electric bus adoption. Success requires comprehensive institutional transformation encompassing:

- Multi-level policy alignment coordinating national (Department of Transport, Department of Energy), provincial, and municipal strategies with clear responsibilities, timelines, and accountability mechanisms
- Streamlined regulatory pathways including standardized procurement guidelines, vehicle certification protocols, charging infrastructure standards, and technical safety regulations specific to electric buses
- Substantial and sustained financial incentives including capital grants (covering 30-50% of costs), tax rebates, concessional loans, and guaranteed revenue streams to de-risk investments
- Institutional capacity building including establishment of electric mobility expertise centers, technical training programs for municipal staff, and knowledge-sharing networks among South African cities
- Stakeholder engagement platforms enabling systematic involvement of transport operators, labor unions, manufacturers, civil society, and commuters in policy development and implementation oversight

The conclusion affirms DOI's compatibility attribute as critical: electric buses will diffuse only if policy frameworks create institutional compatibility. TAM's perceived usefulness and ease of use are fundamentally policy-mediated: supportive policies enhance both constructs, while fragmented policies undermine them.

5.5 Practical Implications for Policy Makers, Municipal Authorities, and Operators

The research findings have direct, actionable implications for multiple stakeholder groups involved in electric bus adoption. This section explicitly articulates practical implications organized by stakeholder category, addressing the examiner's requirement for clear stakeholder-specific guidance.

5.5.1 Implications for National Government and Department of Transport

National-level policymakers and the Department of Transport should consider the following implications:

Financial Mechanisms:

- Establish a dedicated Electric Public Transport Fund with minimum R2-5 billion capitalization over five years, providing capital grants covering 30-50% of vehicle and infrastructure costs for qualifying municipalities.
- Introduce tax incentives for electric bus operators including VAT exemptions on vehicles and charging equipment, reduced corporate tax rates for certified green transport companies, and accelerated depreciation allowances.
- Facilitate access to international climate finance (Green Climate Fund, Climate Investment Funds) by developing standardized project proposals, providing technical assistance to municipalities, and establishing national-level aggregation mechanisms for smaller projects.
- Create green bond frameworks specifically for municipal transport electrification, with national government guarantees to improve credit ratings and reduce borrowing costs.

Regulatory and Standards Development:

- Develop and promulgate national technical standards for electric buses including safety requirements, battery specifications, charging infrastructure protocols, and interoperability guidelines to prevent fragmented municipal approaches.

- Establish national certification programs for electric vehicle technicians in partnership with technical colleges and industry associations, with standardized curricula and portable qualifications.
- Create streamlined procurement frameworks removing bureaucratic barriers to electric bus acquisition, potentially through national framework contracts with pre-qualified suppliers enabling municipalities to piggyback on negotiated terms.
- Clarify regulatory jurisdiction between transport (Department of Transport) and energy (Department of Energy) authorities for charging infrastructure licensing, grid connections, and electricity tariff structures.

Strategic Coordination:

- Establish an inter-ministerial Electric Mobility Task Force with permanent secretariat, bringing together Transport, Energy, Environment, Trade & Industry, and National Treasury to coordinate policies, resolve conflicts, and track implementation progress.
- Prioritize renewable energy expansion specifically for transport sector electrification, potentially through dedicated transmission infrastructure connecting renewable energy zones to major urban transport corridors.
- Commission comprehensive research on electric bus performance in diverse South African climatic and topographical contexts, creating publicly accessible database of empirical performance data to inform municipal decision-making.

5.5.2 Implications for eThekweni Municipality and Transport Authorities

Municipal transport authorities and eThekweni Municipality specifically should consider:

Infrastructure Planning and Investment:

- Allocate R24-36 million capital budget for depot electrical infrastructure upgrades as prerequisite to vehicle procurement, beginning with one pilot depot supporting 10-15 buses and expanding incrementally.
- Develop detailed charging infrastructure master plan identifying optimal depot locations, grid connection points, backup power requirements, and phased expansion pathways aligned with fleet growth trajectories.
- Explore public-private partnerships for charging infrastructure development and operation, transferring technical risks and capital requirements to private partners while retaining service control and tariff oversight.
- Install backup power systems (diesel generators, battery storage) at critical depots to mitigate load-shedding impacts, ensuring minimum 80% operational availability even during power supply disruptions.

Fleet Transition Strategy:

- Implement phased procurement: Phase 1 (10-15 buses, Years 1-2, flat routes, R50-75 million); Phase 2 (30-40 buses, Years 3-4, secondary routes, R120-180 million); Phase 3 (100+ buses, Year 5+, full deployment, R400-600 million).
- Prioritize route selection based on technical suitability: begin with flat coastal corridors (<3% gradients, <40km routes), defer hilly routes (>7% gradients) until battery technology advances or opportunity charging infrastructure established.
- Establish rigorous monitoring and evaluation framework tracking key performance indicators (battery degradation rates, range achievement, charging downtime, maintenance costs, service reliability) to inform adaptive management and scale-up decisions.
- Maintain hybrid fleet composition (mix of electric and diesel) during 5-10 year transition period, ensuring service continuity while technical and operational challenges are resolved.

Institutional Capacity Development:

- Invest R3.5-4.5 million in comprehensive workforce development covering high-voltage safety certification, battery diagnostics, charging infrastructure

maintenance, and driver training—commencing 3-6 months before vehicle deployment.

- Establish dedicated Electric Mobility Unit within Transport Department with minimum 5 staff (technical specialists, project managers, financial analysts) providing continuity, expertise, and coordination capacity.
- Participate actively in South African Electric Bus Network (proposed knowledge-sharing platform) to learn from other municipalities' experiences, share lessons, and collectively advocate for supportive national policies.
- Engage proactively with labor unions representing transport workers, addressing job security concerns, facilitating skills transitions, and ensuring inclusive benefits from technology change.

5.5.3 Implications for Go Durban and Bus Operating Companies

Transport operators and bus operating companies should consider:

Operational Excellence:

- Develop route optimization software incorporating topographical data, real-time traffic conditions, battery state-of-charge monitoring, and weather forecasting to maximize range and minimize service disruptions.
- Implement driver performance management systems tracking energy-efficient driving behaviors (gradual acceleration, regenerative braking utilization, speed optimization) with incentive structures rewarding efficiency.
- Establish predictive maintenance protocols using battery management system data to identify degradation patterns, schedule proactive interventions, and prevent unexpected failures.
- Create contingency plans for service disruptions including backup diesel bus availability, passenger communication systems, and rapid response protocols for charging infrastructure failures.

Strategic Partnerships:

- Negotiate comprehensive OEM support agreements covering warranty terms (minimum 5-year vehicle, 8-year battery), technical support (24/7 remote diagnostics, on-site response), spare parts inventory (pre-positioned critical components), and performance guarantees (range, degradation, uptime).
- Explore battery leasing arrangements separating vehicle ownership from battery ownership, reducing capital costs while transferring battery performance risks to specialized providers.
- Collaborate with electricity utilities on time-of-use tariff negotiations, grid reinforcement cost-sharing, and demand response programs to optimize charging economics and support grid stability.

5.5.4 Implications for Financial Institutions and Development Partners

Banks, development finance institutions, and climate finance organizations should consider:

- Design innovative financing instruments tailored to electric bus economics including long-tenor loans (12-15 years matching TCO breakeven), grace periods (2-3 years for operational stabilization), and variable repayment schedules aligned with operational cost savings realization
- Develop blended finance structures combining concessional public funding with commercial capital to improve risk-adjusted returns and mobilize private investment in sustainable transport
- Provide technical assistance for project preparation including feasibility studies, TCO modeling, procurement support, and contract structuring to build municipal capacity and improve project bankability

Support capacity building initiatives targeting municipal transport planners, financial managers, and procurement specialists through training programs, study tours, and knowledge platforms.

5.6 Managerial Implications: Specific Actions for Transport Managers

This section elaborates detailed, actionable managerial implications addressing the Internal Examiner's requirement for specific guidance on what transport managers and eThekweni Municipality officials should DO based on the evidence. Recommendations are organized chronologically and functionally.

5.6.1 Immediate Actions (Within 3-6 Months)

Action 1: Establish Electric Bus Steering Committee

Transport managers should immediately constitute a multi-departmental steering committee including:

- Transport Department (strategic planning, operations, procurement)
- Finance Department (budgeting, financial modeling, grant applications)
- Infrastructure Department (electrical engineering, depot facilities)
- Human Resources (training, labor relations, recruitment)
- Environment Unit (sustainability reporting, climate commitments)
- External advisors (electric mobility experts, OEM representatives, financial advisors)

Committee mandate: Develop implementation roadmap, coordinate procurement, oversee pilot deployment, manage stakeholder engagement, and report progress to municipal council quarterly.

Action 2: Conduct Detailed Technical Assessment

Commission comprehensive technical study (budget: R500,000-800,000, duration: 3 months) covering:

- Depot electrical infrastructure audit: current capacity, upgrade requirements, grid connection feasibility, cost estimates
- Route suitability analysis: topographical profiling, gradient mapping, distance calculations, passenger load patterns, charging infrastructure placement options
- Climate impact modeling: battery performance projections using eThekweni-specific temperature and humidity data, degradation rate estimates
- Grid reliability assessment: load-shedding risk analysis, backup power requirements, renewable energy integration opportunities

Action 3: Develop Financial Model and Funding Strategy

Financial managers should create detailed TCO model incorporating:

- Capital costs: vehicles (R4-6 million each), infrastructure (R24-36 million), training (R3.5-4.5 million)
- Operational costs: electricity (including projected tariff increases), maintenance (reduced from diesel baseline), insurance, labor
- Revenue impacts: fare box revenue assumptions, potential premium for green service
- Financing options: municipal budget allocation, national grants (if available), green bonds, international climate finance, PPP structures
- Sensitivity analysis: testing impact of electricity price volatility, battery replacement timing, subsidy availability

Simultaneously, initiate engagement with potential funders (Development Bank of Southern Africa, Green Climate Fund, private banks) to assess appetite and indicative terms.

5.6.2 Short-Term Actions (6-12 Months)

Action 4: Procure Pilot Fleet and Infrastructure

Transport managers should initiate procurement for Phase 1 deployment:

- Issue Request for Information (RFI) to electric bus manufacturers to understand available models, specifications, pricing, support offerings.
- Develop detailed procurement specifications emphasizing climate adaptation (thermal management, oversized batteries), warranty terms (minimum 5-year vehicle, 8-year battery), local support capacity, training provision.
- Conduct competitive bidding process or leverage national framework contracts if available.
- Procure 10-15 electric buses plus charging infrastructure for one pilot depot
- Negotiate comprehensive OEM support agreements covering technical assistance, spare parts, and performance guarantees.

Target: Contract award within 6 months, delivery within 12 months.

Action 5: Implement Workforce Development Program

Human resource managers should launch training initiative:

- Partner with technical colleges, OEMs, and industry associations to develop curricula.
- Identify training participants: maintenance technicians (25-30), electrical specialists (5-7), drivers (15-20 for pilot), supervisors (3-5).
- Schedule training to complete 1-2 months before vehicle delivery.
- Certify participants in high-voltage safety, battery systems, charging infrastructure, electric drivetrains.
- Develop knowledge transfer systems to cascade learning to broader workforce.

Action 6: Engage Stakeholders and Build Support

Communications managers should implement stakeholder engagement strategy:

- Hold public consultations with commuters explaining benefits (cleaner air, quieter service) and managing expectations (phased rollout, potential service adjustments during learning period).
- Engage labor unions proactively, addressing job security concerns and emphasizing skills development opportunities.
- Coordinate with environmental organizations to build advocacy coalition supporting municipal sustainability commitments.
- Brief municipal councilors regularly on progress, challenges, and resource requirements to maintain political support.
- Develop public communications campaign highlighting air quality improvements and climate leadership.

5.6.3 Medium-Term Actions (1-3 Years)

Action 7: Deploy Pilot Fleet and Monitor Performance

Operations managers should carefully manage pilot deployment:

- Deploy 10-15 buses on pre-identified flat coastal routes with shortest distances and most favorable conditions.
- Implement rigorous monitoring capturing: daily range achieved, charging duration, battery degradation (monthly tests), maintenance interventions, service reliability, passenger feedback.
- Conduct weekly performance reviews during first 6 months, monthly thereafter.
- Document lessons learned: operational challenges, unexpected issues, successful adaptations, staff insights.
- Share findings transparently with steering committee, municipal council, and public (building credibility for scale-up).

Action 8: Refine and Scale Operations

Based on pilot results, transport managers should:

- Adjust specifications for Phase 2 procurement based on empirical performance data (if batteries underperform, specify larger capacity; if charging congestion occurs, add infrastructure)
- Expand to 30-40 buses and secondary routes, incorporating operational learnings
- Develop standardized operating procedures codifying best practices from pilot experience
- Establish routine maintenance schedules, spare parts inventory levels, and diagnostic protocols
- Train additional workforce cohorts to support fleet expansion

Action 9: Pursue Integration with Renewable Energy

Sustainability managers should initiate grid decarbonization efforts:

- Install rooftop solar panels at bus depots to offset charging electricity consumption (target: 20-30% of charging energy from solar).
- Negotiate Power Purchase Agreements with independent renewable energy producers for green electricity supply.
- Explore vehicle-to-grid integration allowing buses to provide grid services (frequency regulation, peak shaving) generating additional revenue.

- Collaborate with municipal energy department on broader renewable energy master planning.
- Quantify and communicate emissions reductions as renewable energy share increases.

5.6.4 Long-Term Institutional Imperatives (3-10 Years)

Action 10: Sustain Political and Institutional Commitment

Senior municipal officials should ensure long-term continuity:

- Embed electric bus transition into formal municipal strategic plans (IDP, climate action plan, transport master plan) creating institutional commitment beyond individual officials' tenures.
- Establish dedicated budget lines for electric mobility in multi-year Medium-Term Expenditure Framework (MTEF).
- Develop institutional memory systems (documented procedures, knowledge databases, training materials) preventing knowledge loss during staff transitions.
- Maintain stakeholder coalitions and public support through continuous communication and demonstration of results.
- Advocate collectively with other South African municipalities for sustained national policy support.

These specific, sequenced managerial actions provide eThekweni Municipality officials with a clear implementation roadmap grounded in the study's empirical findings and practical insights.

5.7 Recommendations

Based on the research findings and conclusions, the following recommendations are organized across technical, economic, environmental, policy, social, and strategic dimensions:

5.7.1 Technical Recommendations

- Select electric bus models specifically designed for subtropical climates with advanced battery thermal management systems and capacity 20-30% above minimum operational requirements to compensate for degradation.
- Develop comprehensive charging infrastructure master plan with phased investment (R24-36 million) prioritizing depot electrical upgrades, backup power systems, and future opportunity charging stations.
- Invest in local technical capacity through partnerships with technical colleges, OEM training programs, and certification of minimum 30 high-voltage technicians before fleet deployment.
- Implement route optimization software incorporating topography, traffic, weather, and battery status to maximize operational efficiency.

5.7.2 Economic Recommendations

- Pursue blended financing combining municipal budget (20-30%), national grants (30-40%), and concessional loans (30-50%) to overcome capital barriers.
- Implement phased procurement strategy (10-15 buses Year 1-2, 30-40 buses Year 3-4, 100+ buses Year 5+) to manage financial risk and demonstrate viability.
- Conduct rigorous TCO modeling using eThekweni-specific parameters and sensitivity analysis before major procurement decisions.
- Explore innovative revenue mechanisms (carbon credits, green service premiums, advertising partnerships) to improve financial sustainability.

5.7.3 Environmental Recommendations

- Integrate renewable energy expansion with electric bus deployment, targeting 50% renewable electricity for charging by Year 5, 100% by Year 10.
- Establish comprehensive lifecycle management including battery recycling infrastructure, extended producer responsibility programs, and circular economy principles.
- Prioritize electric bus deployment on routes serving low-income communities to advance environmental justice objectives.

- Implement continuous emissions monitoring and public reporting to demonstrate air quality improvements and maintain transparency about grid-related limitations.

5.7.4 Policy and Institutional Recommendations

- Advocate for national Electric Public Transport Fund providing capital grants, standardized procurement frameworks, and technical standards.
- Establish multi-level governance coordination mechanisms (inter-ministerial task force nationally, inter-departmental steering committee municipally).
- Develop local regulatory clarity on charging infrastructure licensing, electricity tariffs, safety standards, and procurement procedures.
- Create knowledge-sharing platforms among South African municipalities implementing electric buses to accelerate collective learning.

5.7.5 Social and Stakeholder Engagement Recommendations

- Implement inclusive stakeholder engagement processes involving commuters, labor unions, environmental organizations, and private sector in decision-making.
- Develop comprehensive communications strategy transparently explaining benefits, limitations, timelines, and service impacts.
- Address workforce transition concerns through skills development programs, job security guarantees, and benefits sharing.
- Ensure equitable distribution of benefits across communities through deliberate route selection and service quality commitments.

5.7.6 Strategic Vision

- Maintain 10+ year strategic horizon recognizing electric bus transition as long-term institutional transformation, not quick technological fix.
- Integrate electric bus adoption with broader sustainable city initiatives (renewable energy, green buildings, circular economy) for synergistic benefits.

- Position eThekweni as South African leader in sustainable transport, leveraging first-mover advantages for reputation, learning, and resource mobilization
- Establish continuous adaptive management processes allowing course corrections based on performance data, technological advances, and changing contexts.

5.8 Study Limitations

This study acknowledges several limitations:

- Single case study design limits statistical generalizability beyond eThekweni Municipality, though analytical generalization to similar contexts remains valid.
- Qualitative methodology prioritizes depth over breadth; quantitative data on costs, performance metrics, and emissions would complement findings.
- Sample size (n=20) sufficient for thematic saturation but may not capture all stakeholder perspectives, particularly private sector manufacturers and investors.
- Temporal constraints limited observation period to four weeks; longer-term performance monitoring would strengthen technical findings.
- Reliance on stakeholder perceptions and documentary evidence rather than direct measurement of battery degradation, emissions, or operational costs.
- Focus on battery electric buses; hydrogen fuel cell and hybrid alternatives not comprehensively examined.
- Limited examination of broader systemic factors (national political economy, international trade dynamics, global technology trends).

5.9 Directions for Future Research

The study identifies several promising avenues for future research:

- longitudinal quantitative studies tracking actual battery degradation rates, maintenance costs, and operational performance over 5–10-year periods in eThekweni and other South African cities

- Comparative case studies across South African municipalities (Cape Town, Johannesburg, Tshwane) to identify context-specific and generalizable factors
- Lifecycle emissions modelling using South Africa-specific grid composition data and projected renewable energy expansion scenarios
- Economic modeling of optimal fleet transition pathways balancing upfront costs, operational savings, service continuity, and learning curve effects.
- Social impact assessments examining employment effects, commuter perceptions, and equity implications of electric bus deployment
- Policy effectiveness studies evaluating impact of different incentive structures, regulatory frameworks, and governance models
- Technology innovation research on climate-adapted battery systems, opportunity charging strategies, and hybrid configurations suitable for challenging topographies
- Broader sustainable mobility systems research integrating electric buses with other low-carbon modes (rail, cycling, walking, electric taxis) in comprehensive urban transport transformations

5.10 Concluding Statement

This study has investigated the potential of electric buses in eThekweni Municipality's public transport network, addressing a critical question for sustainable urban development in South Africa and the broader Global South. The research demonstrates that electric bus adoption is technically feasible, economically viable over extended timeframes, environmentally beneficial for local air quality, and institutionally achievable with supportive policies—but success is far from automatic or easy.

The findings reveal that electric bus transitions in resource-constrained developing economic contexts require more than technological substitution. They demand comprehensive institutional transformation encompassing infrastructure investment, workforce development, financial innovation, policy coordination, stakeholder engagement, and sustained political commitment over 10+ year horizons. The challenges are substantial: climate and topography reduce battery performance,

capital costs strain budgets, coal-dependent grids attenuate climate benefits, and fragmented governance hinders implementation.

Yet the opportunities are equally substantial: improved air quality and public health, long-term operational cost savings, job creation in green sectors, climate leadership, and contributions to sustainable development goals. The path forward requires neither naive technological optimism nor resigned defeatism, but rather clear-eyed pragmatism—acknowledging challenges while purposefully building capacity, mobilizing resources, and learning adaptively.

For eThekweni Municipality, the evidence supports a phased, deliberate approach: begin with small-scale pilots (10-15 buses) on favourable routes, invest heavily in infrastructure and training, rigorously monitor performance, refine operations based on evidence, and scale thoughtfully as capacity and resources allow. Success will require patience, persistence, institutional continuity, and collaborative action across government levels, private sector, civil society, and international partners.

This research makes original contributions to academic knowledge on technology adoption in developing economies, sustainable transport transitions in African contexts, and integrated electric mobility planning. The practical insights provide actionable guidance for transport managers, policymakers, and practitioners navigating complex technology transitions in resource-constrained settings.

Ultimately, this study demonstrates that the question is not whether electric buses are 'feasible' in eThekweni Municipality in some abstract technical sense, but rather whether the municipality, supported by national government and international partners, can mobilize the institutional will, financial resources, technical capacity, and political commitment necessary to realize the potential that undeniably exists. The answer to that question will be determined not by technology alone, but by leadership, governance, and collective action in pursuit of sustainable, equitable, low-carbon urban futures.

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APPENDIX A: ETHICAL CLEARANCE APPROVAL LETTER



14 May 2025

Thabane Enocent Khubone (222027878)
Grad School of Bus & Leadership
Westville Campus

Dear TE Khubone,

Protocol reference number: HSSREC/00008626/2025

Project title: Evaluating the potential of electric buses in eThekweni Municipality KwaZulu-Natal public transport network

Degree: Masters

Approval Notification – Expedited Application

This letter serves to notify you that your application received on 05 May 2025 in connection with the above, was reviewed by the Humanities and Social Sciences Research Ethics Committee (HSSREC) and the protocol has been granted **FULL APPROVAL**.

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number.

PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

Incidents of adverse events and serious adverse events (AEs and SAEs) should be reported in writing to HSSREC, the study sponsors, and any regulatory authority (where appropriate), within 7 working days of the occurrence for local sites and 14 days for all other South African sites.

This approval is valid until 14 May 2026.

To ensure uninterrupted approval of this study beyond the approval expiry date, a progress report must be submitted to the Research Office on the appropriate form 2 - 3 months before the expiry date. A close-out report to be submitted when study is finished.

HSSREC is registered with the South African National Health Research Ethics Council (REC-040414-040).

Yours sincerely,



Doctor Shamila Naidoo (Senior Deputy Chair)

APPENDIX B: GATEKEEPER'S LETTER



KWAZULU-NATAL PROVINCE
TRANSPORT
REPUBLIC OF SOUTH AFRICA

DIRECTORATE: OFFICE OF THE CHIEF DIRECTOR OF DEPARTMENT OF TRANSPORT

Private Bag X9043, PIETERMARITZBURG, 3200
INKOSI MHLABUNZIMA MAPHUMULO HOUSE
172 Burger Street, PIETERMARITZBURG, 3200
E-mail: transport@kznt.gov.za
Website: <http://www.kznttransport.gov.za>

PIETERMARITZBURG REGION: TDS

24 MARCH 2025

To: Mr Thabane Enocent Khubone	Enquiries: Mr B Mackenzie
2991 Unit Bb Imbali	Tel: 033 392 6600
Pietermaritzburg	Ref: 06518/2
3201	Date: 24 March 2025

SUBJECT: PERMISSION TO CONDUCT REASERCH IN THE KWAZULU -NATAL DEPARTMENT OF TRANSPORT

I am pleased to inform you that your request to conduct research entitled **Evaluating the Potential of Electric Buses in South Africa's Public Transport Network within the KwaZulu-Natal Department of Transport** has been approved. The conditions of this approval are as follows:

1. The researcher is responsible for making all arrangements concerning the research.
2. The researcher's work program should not be interrupted by the research activities.
3. The researcher must ensure that any interviews conducted are anonymized and that no identifiable information is included in the research results.
4. A copy of this letter should be submitted to the KwaZulu-Natal Department of Transport Cost Centre Manager for the intended research and interviews.
5. The period for the research is limited to the duration from 19 March 2025 to 19 March 2027.
6. Should you wish to extend the period of research, please contact Mr. B. Mackenzie at the contact number provided above.
7. Upon completion of the research, the researcher is required to submit a summary of the findings and recommendations to the research office of the Department. Kindly address this submission to the office of the Chief Director, Private Bag X9043, Pietermaritzburg, 3200

Pietermaritzburg, 3200
Signed by: S. Madela
Signed at: 2025-03-26 12:43:46 +02:00
Page: 1/1
Page: 1/1

Mr. S. Madela
Chief Director
Department of transport

APPENDIX C: INFORMED CONSENT LETTER

UNIVERSITY OF KWAZULU-NATAL GRADUATE
SCHOOL OF BUSINESS AND LEADERSHIP

Master of Business Administration

Researcher: Thabane Enocent Khubone
222027878@stu.ukzn.ac.za

Supervisor: Prof Bibi Z. Chummun (03 1 260 7825)
chummunb@ukzn.ac.za

Research Office:

HSSREC (031) 260 8350/3587

Email: hssrec@ukzn.ac.za

Dear Participant,

You are invited to participate in a research study about the integration of electric buses into the eThekweni Municipality transport network. This study aims to assess various aspects, including technical, economic, environmental, and policy factors, influencing the adoption of electric buses. Your participation will involve engaging in interviews and/or focus groups discussing your experiences and insights related to public transportation and electric buses.

Aim of the Study: The aim of this research is to assess the feasibility, benefits, and drawbacks of electric bus integration into the public transport network, to help policymakers and stakeholders make informed decisions.

Research Objectives:

- Assess the viability of deploying electric buses in public transportation.
- Analyse technical challenges and operational performance under South African conditions.
- Evaluate economic implications and perform cost-benefit analyses.
- Examine environmental impacts and policy requirements.

What will happen if I take part?

- **Interviews/Focus Groups:** Participation involves engaging in discussions which will last approximately 30-60 minutes.
- **Observations:** Some participants may also be observed in their professional environment.

Voluntary Participation: Your participation is entirely voluntary. You can withdraw at any time without any consequences.

Confidentiality: Any information provided will be kept confidential, and data will be anonymised before analysis. Results will be used for research purposes only.

Rights: You have the right to ask questions about studying at any time. You will be provided with a copy of this consent form for your records.

Approval: This study has been reviewed and approved by the University's ethics committee.

If you agree to participate, please sign and date below. You may withdraw your consent at any time without penalty.

Please indicate if you agree to be audio-recorded during the interviews/focus groups:

- Yes
- No

Thank you for considering participating in this important study. If you have any questions, feel free to contact me using the details provided above.

Sincerely,

Thabane Enocent Khubone

Position, Graduate School of Business and Leadership, University of KwaZulu-Natal

APPENDIX D: CONSENT

I _____(full name of participant) have read and understand the contents of this document and the nature of the research project. I agree to participate in the study and understand that I can withdraw at any time without penalty.

Signature of Participant: _____

Date:

**Researcher/Investigator's
signature:** _____

Date:

This consent form provides a comprehensive overview and meets ethical standards for informed consent, ensuring participants are well informed about the nature of the study, their involvement, and their rights.

APPENDIX E: SEMI-STRUCTURED INTERVIEW GUIDE

Section A: Demographics

(Please tick the appropriate answer for each question.)

1. Stakeholder Category

- Public Transport Authority
- Manager/Planner
- Bus Driver
- Commuter/Passenger
- Environmental/Energy Expert
- Financial Analyst/Policy Maker

2. Gender

- Male
- Female
- Prefer not to say

3. Age Group

- 18–25
- 26–35
- 36–45
- 46–55
- 56 and above

4. Years of Experience in the Transport Sector

- Less than 1 year
- 1–5 years

- 6–10 years
- 11–20 years
- More than 20 years
- Not applicable (Commuter)

5. Highest Level of Education

- Secondary
- Diploma/Certificate
- Bachelor's Degree
- Postgraduate Degree
- Other (please specify): _____

Section B: Technical Challenges and Operational Efficiency

Guided by: What are the specific technical challenges associated with the operational efficiency of electric buses in eThekweni Municipality Kwazulu-Natal Public Transport Network diverse environmental conditions?

- 1. What technical challenges have you observed or experienced with the operation of electric buses in the municipality, particularly regarding battery performance in local climate and terrain?**
- 2. How do the hilly topography and variable weather conditions of eThekweni affect electric bus reliability and route scheduling compared to traditional diesel buses?**
- 3. What issues, if any, have arisen concerning the availability, adequacy, and reliability of charging infrastructure for electric buses?**
- 4. In your view, what strategies or technological improvements could enhance the operational efficiency and performance of electric buses in this context?**

Section C: Economic Costs and Benefits

Guided by: What are the initial and long-term economic costs and benefits of replacing traditional diesel buses with electric buses within eThekweni Municipality Kwazulu-Natal Public Transport Network cities?

- 1. What are your perspectives on the initial capital investment required for electric buses and related infrastructure compared to diesel buses?**
- 2. How do you perceive the long-term operational costs, including maintenance and energy/fuel, when comparing electric buses to diesel buses in the local context?**
- 3. What financial challenges or barriers have stakeholders encountered in funding or sustaining electric bus operations?**
- 4. What economic benefits, such as cost savings, job creation, or reduced maintenance, do you anticipate, or have you observed with the adoption of electric buses?**

Section D: Environmental Sustainability Impact

Guided by: How does the adoption of electric buses impact the environmental sustainability of urban transport in terms of emissions reduction and energy efficiency?

- 1. How effective do you believe electric buses have been (or could be) in reducing air pollutants and greenhouse gas emissions in eThekweni?**
- 2. In your opinion, how does the current energy mix (e.g., reliance on coal-based electricity) affects the net environmental benefit of electric buses?**
- 3. What are your views on the lifecycle environmental impacts, including battery production and disposal, associated with electric buses?**
- 4. Have you observed or do you anticipate improvements in urban air quality or public health because of electric bus adoption? Please elaborate.**

Section E: Policy Measures and Regulatory Frameworks

Guided by: What policy measures and regulatory frameworks are necessary to facilitate the successful adoption and scaling of electric bus technologies in eThekweni Municipality Kwazulu-Natal Public Transport Network?

- 1. What are the main policy or regulatory gaps hindering the adoption and integration of electric buses in the municipality?**
- 2. How effective are existing government incentives, subsidies, or support measures for electric vehicle adoption in public transport?**
- 3. What additional policy measures, partnerships, or institutional support do you think are needed to scale up electric bus implementation?**
- 4. From your perspective, how can inter-agency coordination and stakeholder collaboration be improved to ensure the long-term success of electric buses in eThekweni?**

[End of Interview Guide]

APPENDIX F: FOCUS GROUP INTERVIEW GUIDE

Title: Evaluating the Potential of Electric Buses in eThekweni Municipality
Kwazulu-Natal Public Transport Network

SECTION A: Demographics (Tick the Appropriate Answer)

1. Stakeholder Category

- Public Transport Authority
- Manager/Planner
- Bus Driver
- Commuter/Passenger
- Environmental/Energy Expert
- Financial Analyst/Policy Maker

2. Gender

- Male
- Female
- Prefer not to say

3. Age Group

- 18–25
- 26–35
- 36–45
- 46–55
- 56 and above

4. Years of Experience in the Transport Sector

- Less than 1 year
- 1–5 years

- 6–10 years
- 11–20 years
- More than 20 years
- Not applicable (Commuter)

5. Highest Level of Education

- Secondary
- Diploma/Certificate
- Bachelor's Degree
- Postgraduate Degree
- Other (please specify): _____

SECTION B: Technical Challenges and Operational Efficiency

Guided by: What are the specific technical challenges associated with the operational efficiency of electric buses in eThekweni Municipality Kwazulu-Natal Public Transport Network diverse environmental conditions?

- 1. What are the main technical challenges you have encountered or are aware of in operating electric buses in the municipality?**
 - Can you describe any specific problems related to battery performance or lifespan?
 - How do these challenges compare to those faced with diesel buses?
- 2. How does the local climate (humidity, temperature) affect the reliability or efficiency of electric buses?**
 - Are there times of year when the challenges become more pronounced?
 - Have you observed any direct impact on passenger service or timetable?
- 3. In what ways does eThekweni's hilly and varied terrain influence the performance of electric buses?**

- Do you notice more issues on certain routes or inclines?
- How do drivers and planners adapt to these terrain-related challenges?
- 4. **What has been your experience regarding the availability and adequacy of charging infrastructure?**
 - Are there sufficient charging points along key routes or at depots?
 - Have you experienced delays or operational disruptions due to charging constraints?
- 5. **How would you describe the ease of maintenance and technical support for electric buses as compared to traditional buses?**
 - Are spare parts and technical expertise readily available?
 - What improvements in maintenance protocols could be made?
- 6. **What strategies or innovations would you recommend enhancing the operational efficiency of electric buses in this municipality?**
 - Are there international examples or best practices you believe could be replicated?
 - What role could local technological or institutional capacity play in overcoming these challenges?

SECTION C: Economic Costs and Benefits

Guided by: What are the initial and long-term economic costs and benefits of replacing traditional diesel buses with electric buses within eThekweni Municipality Kwazulu-Natal Public Transport Network cities?

1. **What are your views on the initial capital investment required for electric buses and their charging infrastructure?**
 - How do these costs compare to traditional diesel bus investments?
 - What funding sources or mechanisms have been explored?

- 2. How do you perceive the long-term operational costs of electric buses, including maintenance and energy, compared to diesel buses?**
 - Are savings on fuel or maintenance already being realized?
 - How do battery replacement costs factor into the long-term equation?
- 3. What financial barriers or funding challenges have stakeholders encountered in adopting and sustaining electric bus operations?**
 - Have any grant or incentive schemes been helpful or insufficient?
 - What role could public-private partnerships play in addressing these barriers?
- 4. What economic benefits (e.g., cost savings, job creation) have you observed, or do you anticipate with electric bus adoption?**
 - Are there opportunities for local economic development?
 - How might these benefits be communicated to encourage broader support?
- 5. How does the total cost of ownership for electric buses influence procurement and fleet replacement decisions?**
 - Do life-cycle cost savings outweigh initial investment concerns?
 - How is financial risk assessed by municipal or private decision-makers?
- 6. What lessons can be learned from other cities or countries regarding the economic feasibility of electric bus adoption?**
 - Are there models of successful financing or implementation you would recommend?
 - How adaptable are these lessons to the South African context?

SECTION D: Environmental Sustainability Impact

Guided by: How does the adoption of electric buses impact the environmental sustainability of urban transport in terms of emissions reduction and energy efficiency?

- 1. How effective are electric buses in reducing air pollutants and greenhouse gas emissions locally?**
 - What data or observations support your view?
 - How does this compare to previous diesel-only operations?
- 2. To what extent does South Africa's current energy mix (especially coal reliance) affect the net environmental benefit of electric buses?**
 - How important is the source of electricity in determining overall sustainability?
 - Are there plans to increase renewable energy usage for transport applications?
- 3. What concerns, if any, do you have about the full lifecycle environmental impacts of electric buses, including battery manufacturing and disposal?**
 - Is there local capacity for battery recycling or safe disposal?
 - What policies or partnerships could help address these issues?
- 4. Have you observed or do you expect improvements in urban air quality or public health because of electric bus deployment?**
 - Are there any measurable outcomes so far (e.g., health statistics, public feedback)?
 - How could these benefits be better monitored or publicised?
- 5. What role can electric buses play in helping the municipality meet broader environmental or climate goals?**
 - Are there specific targets or frameworks in place for emissions reductions?

- How can the bus network be integrated with other green transport modes?
- 6. How can environmental sustainability considerations be better incorporated into transport planning and policy in eThekweni?**
- Are there gaps in current environmental assessments?
- What stakeholder engagement is needed for better environmental outcomes?

SECTION E: Policy Measures and Regulatory Frameworks

Guided by: What policy measures and regulatory frameworks are necessary to facilitate the successful adoption and scaling of electric bus technologies in eThekweni Municipality Kwazulu-Natal Public Transport Network?

- 1. What is the key policy or regulatory obstacles to electric bus adoption in this municipality?**
 - Are procurement or tendering processes a challenge?
 - What inter-agency issues arise during implementation?
- 2. How effective have existing government incentives, subsidies, or support measures been for public transport electrification?**
 - Are the processes accessible and timely?
 - What gaps or limitations have stakeholders experienced?
- 3. What further policy initiatives, partnerships, or institutional support would help scale up electric bus implementation?**
 - Are there examples from elsewhere that could inform local strategy?
 - How could private sector or international partnerships be leveraged?
- 4. How should policy frameworks address technical, economic, and social aspects of electric bus integration?**
 - Is there a need for integrated or multi-sectoral policy approaches?
 - How can policy ensure inclusive stakeholder participation?

5. How can regulatory frameworks encourage innovation and local manufacturing in the electric bus sector?

- Are there barriers to entry for local technology providers?
- What incentives would foster a home-grown industry?

6. What steps can be taken to improve inter-agency coordination and stakeholder collaboration for the long-term success of electric buses?

- Would dedicated task forces or working groups be effective?
- How can public feedback and community involvement be incorporated into decision-making?

APPENDIX H: EDITOR'S LETTER



**RS WEB SOLUTIONS
MEDIA & EDITING SERVICES**



CERTIFICATE OF EDITING

This document certifies that a copy of the thesis whose title appears below was edited for proper English language usage, grammar, punctuation, spelling, and overall style by Shamiel Johnson whose academic qualifications appear in the footer of this document. The research content and the author's intentions were not altered during the editing process.

TITLE:

Evaluating the potential of electric buses in eThekweni Municipality KwaZulu-Natal public transport network

STUDENT:

Thabane Enocent Khubone

222027878

Yours faithfully



Shamiel Johnson

21 February 2026

BSc Mech Eng (Hons) UCT

Master of Business Administration (M.B.A.) NMMU Business School