

Critical Success Factor (CSF) of Electric Bus Friendly Terminal Design

Mac Arthur Dalan Sanggah, *Sayed Muhammad Aiman Sayed Abul Khair, Jamaludin Muhamad, Farid Al Hakeem Yuserrie, Mohd Nasrudin Hasbullah

Department of Built Environment Studies and Technology, Faculty of Built Environment, Universiti Teknologi MARA, Perak Branch, 32610, Seri Iskandar, Perak, Malaysia

*Corresponding author email (institution email): sayed705@uitm.edu.my

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ABSTRACT - Sustainable urban mobility is a core pillar of modern city planning, aiming to reduce environmental impact while improving accessibility, efficiency, and quality of life. It promotes integrated, low-carbon transportation systems that encourage a shift from private to shared and eco-friendly modes of travel. This study investigates the critical success factors (CSFs) in integrating electric buses (EBs) into the design of Malaysian bus terminals, to support a national transition toward “sustainable urban mobility”. Recognising the challenges of shifting from fossil fuel-based transportation to electric alternatives, the research identifies critical design, operational, and policy-related factors that influence successful implementation. Using document and content analysis, 50 global best-practice articles were examined and adapted to the Malaysian context to bridge existing local knowledge gaps. Insights drawn from international case studies inform the identification of seven key factors: infrastructure readiness, environmental sustainability, technological integration, policy and financial mechanisms, operational efficiency, passenger experience, and stakeholder collaboration. Based on these findings, the study proposes a comprehensive design framework for future electric bus terminals, emphasising 3 themes consisting of modular spatial planning, renewable energy systems, and user-centric facilities. The proposed framework offers valuable guidance for urban planners, policymakers, and transportation stakeholders, contributing to the development of low-carbon, efficient public transit infrastructure aligned with Malaysia’s Smart Mobility Strategy and Low-Carbon City Framework.

INTRODUCTION

Public transportation systems form a vital component of urban infrastructure by offering affordable and accessible services, alleviating traffic congestion, and supporting environmental sustainability. Public transit encourages a modal shift from private vehicles to shared transportation, thereby reducing carbon emissions, fostering community well-being, and enhancing overall quality of life (Litman, 2021). Malaysia’s transportation journey, which began during the colonial era, has since evolved to include modern rail networks, bus rapid transit systems, and other innovative solutions. Recent strategic initiatives, such as the Twelfth Malaysia Plan and the National Energy Transition Roadmap (Ministry of Transport Malaysia, 2021), have accelerated improvements to meet the demands of rapid urbanisation and to integrate electric vehicles (EVs) into the public transport sector.

The adoption of electric buses (EBs) presents a promising approach to achieving low-carbon city objectives by reducing greenhouse gas emissions, minimising urban noise pollution, and improving operational efficiency (Albrechtowicz, 2023). However, several challenges, including limited charging infrastructure, high initial investment costs, and insufficient policy support, remain major barriers to

widespread implementation (Muzir et al., 2022). These issues are particularly relevant when considering the role of bus terminals, which currently lack the infrastructure and flexibility needed to support EV integration, including renewable energy capabilities and user-focused features (Bachok et al., 2014).

There is an urgent need for a structured framework built upon critical success factors (CSFs) to guide the design and operation of EV-compatible bus terminals. Such a framework would significantly enhance functionality, user experience (UX), and operational efficiency, while aligning with Malaysia's vision for sustainable urban mobility (UN-Habitat, 2022).

This study aims to identify the CSFs necessary for integrating electric buses into bus terminal infrastructure by analysing the best global practices and proposing a comprehensive implementation framework. The insights generated are intended to support policymakers, urban planners, and key stakeholders in developing efficient and sustainable transportation systems that are adaptable to diverse urban environments worldwide.

MOTIVATION FOR THIS WORK

Rapid urbanisation has led to a rising demand for sustainable and efficient public transport in Malaysia, with the current systems requiring modernisation to address those needs. Today, the design, facilities, and efficiency of most bus terminals are inadequate and not in line with the Smart Mobility and Low-Carbon-City agendas of Malaysia (Richard Wee & Jasmin Nga, 2024). Integrating electric buses (EBs) into these terminals offers a promising solution for reducing greenhouse gas emissions and enhancing energy efficiency in urban transit. Guided by the global commitment outlined in the 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs) (2024), this study is motivated by the urgent need to lower carbon footprints through sustainable transport initiatives.

The research aims to address critical design and operational gaps, particularly the lack of renewable energy-powered charging infrastructure, to inform the development of inclusive and efficient transportation hubs. Beyond improving user experience, these improvements are expected to accelerate Malaysia's transition toward a low-carbon future and provide a replicable framework for sustainable urban mobility in other regions.

PROBLEM STATEMENT

Malaysia's Low Carbon City initiative emphasises the integration of electric vehicles (EVs) and the necessary charging infrastructure as a key component of sustainable urban development (Ivan Loh, 2023). However, a comprehensive framework specifically tailored for electric bus-friendly terminals has yet to be established. Existing bus terminals remain largely inefficient, lack user-centric design, and are not well-adapted to support the transition toward green mobility (Richard Wee & Jasmin Nga, 2024). To realise the objectives outlined in Malaysia's Smart Mobility Strategy and the Low Carbon City Initiative, these shortcomings must be addressed. A well-structured and holistically integrated framework for electric bus implementation in terminal design is essential to enhance the sustainability, efficiency, and future readiness of the public transportation system (Twelfth Malaysia Plan, 2021).

RESEARCH AIM

This research aims to develop a framework of critical success factors (CSFs) for electric bus terminal design and to derive insights that can guide the enhancement of bus terminals to effectively support electric bus infrastructure integration.

RESEARCH OBJECTIVES AND QUESTIONS

This research aims to explore the critical success factors (CSFs) required for bus terminals to effectively adapt to electric bus operations. The study is guided by three primary objectives: (1) to identify key success factors in effective bus terminal design, (2) to analyse the factors influencing the adoption of electric buses within terminal infrastructure, and (3) to develop a structured framework that enables the seamless integration of electric buses into terminal design. To achieve these objectives, the study addresses the following research questions: What are the critical success factors in bus terminal design? What are the essential factors for adopting electric buses in terminal infrastructure? How can a framework be developed to support this transition? By answering these questions, the study aims to offer a comprehensive understanding of the design, operational, and strategic considerations necessary for the successful implementation of electric bus terminals.

SIGNIFICANCE OF THE STUDY

This study aims to enhance the design of bus terminals in Malaysia to better accommodate electric buses (EBs), thereby improving public transportation efficiency and user experience. By identifying the Critical Success Factors (CSFs), the research provides a guideline for upgrading existing terminals in alignment with the UN-Habitat Smart Mobility Strategy. Furthermore, it supports Malaysia's low-carbon urban development goals by promoting the integration of electric vehicles (EVs) into the public transport system. Increased adoption of public transport is expected to reduce carbon emissions and advance Sustainable Development Goal 11 (SDG 11), which focuses on sustainable cities and mobility.

The research is based on secondary data analysis and is limited to intercity bus terminals in Malaysia, as guided by the Low-Carbon Mobility Blueprint 2021–2030. Therefore, the findings may not be fully generalizable to other regions or types of transportation. The study specifically focuses on electric buses and excludes other transport modes. Constraints such as limited expert input, restricted access to public data, and gaps in current literature have influenced the depth of analysis. To enhance the robustness and applicability of the proposed framework, future research should incorporate primary data collection, comparative case studies from other countries, and a broader examination of multimodal transport systems.

Ultimately, this study identifies the critical success factors for the adoption of electric buses in Malaysian bus terminals, emphasising the transition from fossil fuel to electric mobility. Through a thematic analysis of existing literature, the research develops a conceptual framework for electric bus terminal design. This framework serves as a foundation for future studies on infrastructure readiness, charging requirements, and sustainable mobility planning.

LITERATURE REVIEW

Public Transportation and Urban Sustainability

Public transportation is an important component of urban development infrastructure that supports the cities' function and residents. Public transportation is defined as a medium of transportation that transports people using vehicles such as buses, trains, subways and trams (Zavyalov, 2016). Public transportation plays a crucial role in providing economical travel options, alleviating vehicular congestion, enhancing air quality, and fostering community sustainability. Utilising public transit systems enables individuals to advance the creation of a more resilient environment, unified communities, and a streamlined transportation infrastructure, ultimately culminating in a better quality of life for all stakeholders (American Public Transportation Association, 2010). Public transport also promotes social cohesion by providing accessible mobility options for all community members, thus enhancing social inclusion. It also connects a diverse group of people, allowing for greater interaction and community building (Advancing Public Transport, 2023).

According to Zavyalov (2016), the positive impact of public transportation is reducing pollution by offering an alternative to private transportation toward public transport which can lower the greenhouse gas emissions and improve air quality in urban areas. Moreover, Sustainable public transport is designed to minimise the energy consumption and emissions that contribute to a healthier environment. It is also supported by Ustadi & Shopi (2016a) that stated the public transportation reduces pollution and traffic congestion, which can lower the healthcare costs caused by pollution-related illnesses. Reducing reliance on private vehicles helps to combat climate change and urban heat islands. Moreover, it is lowering emissions and promoting the use of electric or alternative low-emissions vehicles (Advancing Public Transport, 2023).

According to Iman Hashim & Munirah Syuhada Mohamad Zan (2019), a well-designed public transport system can improve accessibility to local businesses, enhancing their sale and profitability. Public transportation system also acts as an economic catalyst for economic development by improving accessibility to jobs, education and services. Public transportation integration of people movement is important got local businesses and overall economic growth. An efficient public transportation system contributes to reducing traffic congestion, which leads to time saving and increased productivity. It also plays an important role in promoting social equity by providing mobility options for all society, including those without access to private vehicles (Zavyalov, 2016).

Public transport system contributes to urban resilience by implementing adaptable infrastructure that can respond to changes in demographic needs and urban dynamics (Advancing Public Transport, 2023). Zavyalov (2016) stated that the public transportation system influences urban planning to have the efficient integration of land use patterns, encouraging high-density development

and can lead to walkable communities. Urban planners often emphasise the importance of public transportation to align with urban growth to create sustainable cities.

Evolution of Public Transportation

Malaysia's transportation system began in 1903, primarily through land transport, to support the socioeconomic activities related to rubber and tin mining. Railways evolved significantly, initially with steam trains and later transitioning to electric trains (KTMB). The evolution of railways has been marked by significant advancements, commencing with steam locomotives and subsequently transitioning towards electric trains (KTMB). Modern rail transport includes a diverse range of models, such as heavy rail systems, commuter rail networks, light rapid transit (LRT), monorail systems, and airport rail connections, coupled with the integration of funicular railways. The present emphasis within railway infrastructure development is directed towards enhancing connectivity between Malaysia and its neighbouring nations, particularly through initiatives such as the East Coast Railway Link (ECRL), which aims to establish a link with Singapore, expected to reach completion by the year 2027. As rail infrastructure expanded, it enabled more Malaysians to shift to public transportation by enhancing capacity for large numbers of passengers while utilising fewer resources like fuel and land, contributing to environmental sustainability (Kumarran et al., 2023).

National Energy Transition Roadmap & Ministry of Economy (2023) highlighted the aim of Malaysian government initiatives to align with the Paris Agreement to reduce Carbon emissions 45% by 2050. NETR aim for Malaysia to reach net-zero greenhouse gas (GHG) emissions by 2050, emphasising an energy transition from fossil fuel-based energy systems to renewable and low-carbon energy. Moreover, this initiative is followed by public transport electrification. It is conducted by upgrading the infrastructure of the bus depot to facilitate electric bus charging. The NETR also aim to increase the public transport modal share from 40% by 2040 to 60% by 2050 to initiate the Green Mobility Target. Enhancing green mobility is also part of the strategy in the Twelfth Malaysia Plan (2021) through the implementation of green mobility initiatives, master plans and design guidelines for green mobility at the local level will be developed, while relevant legislation at the federal and state levels.

Key Design Component for Bus Terminals

Urban transport networks rely heavily on bus terminals as central nodes that connect commuters to various modes of transportation while promoting affordable and accessible mobility. Effective terminal design should prioritise user experience, operational functionality, and long-term sustainability. According to Logeswaran et al. (2021), optimal layouts should focus on efficient space utilisation, smooth passenger flow, and integrated safety management. Modular and scalable designs allow flexibility for future expansion and evolving user needs.

Accessibility and user experience are critical to successful terminal design, particularly for diverse user groups such as the elderly and people with disabilities. Key features include ramps, tactile surfaces, clear signage, and real-time information systems to enhance navigation and usability (Othman et al., 2022). Safety is another essential component; adequate lighting, surveillance systems, and well-designed spaces contribute to physical security and help foster user trust (Logeswaran et al., 2021).

Moreover, integrating terminals with the surrounding urban environment promotes walkability and supports local economic activity, enhancing the vibrancy and livability of cities (Bachok et al., 2014). Sustainability is also a cornerstone of terminal design. The incorporation of renewable energy solutions—such as solar-powered charging stations and energy-efficient systems—reduces environmental impact (Lyu et al., 2019). These environmentally responsible strategies not only lower emissions but also contribute to broader efforts to combat climate change and improve public health.

Bus Terminal

Bachok et al. (2015) stated that improvements in transportation terminals, integrated public transport interchange facilities, and mixed-use building components, including commercial and waiting areas, have contributed to urban renewal. Bus terminals serve an important role in the transportation system, serving as nodes and linkages for passenger flow within the terminal area. Several elements influence the design of bus terminals, including location, application, permit requirements, operational standards, and security laws (Logeswaran et al., 2021).

Terminal layout and Functionality

An efficient bus terminal is one that effectively addresses the issues of intersecting pedestrian and vehicle flows, has a well-organised layout for ticketing and waiting areas, and includes necessary facilities to enhance passenger comfort and safety. These improvements led to significant enhancements in space utilisation, passenger safety, and overall operational efficiency, setting a benchmark for what constitutes an efficient bus terminal (Li, 2021).

Malaysian bus terminals offer numerous advantages that enhance the efficiency, connectivity, and convenience of the public transportation network. Serving as major hubs for intercity and local buses, these terminals benefit both passengers and the entire transport network. For instance, the Terminal Bersepadu Selatan (TBS) in Kuala Lumpur is an example of a modern transportation hub facilitating seamless intermodal connections among buses, trains, and other modes. By centralising transit operations, TBS optimises travel time management and reduces road congestion. Equipped with modern amenities, TBS enhances safety, promotes tourism, supports economic growth, and fosters sustainable urban planning, serving as a model of integrated public transport (Wang & Yi, 2016).

According to Logeswaran et al. (2021), the entire transport terminal is conceptualised as a network of Nodes (facilities) and Links (paths for passenger flow). An efficient terminal layout and functionality are crucial for the design of bus terminals in urban areas. Proper planning of the layout is essential to ensure the seamless movement of buses, people, and vehicles within the terminal grounds. Li (2021) stated that functional areas such as information desks, ticketing platforms, restrooms, and medical facilities should be strategically placed to ensure easy access and visibility.

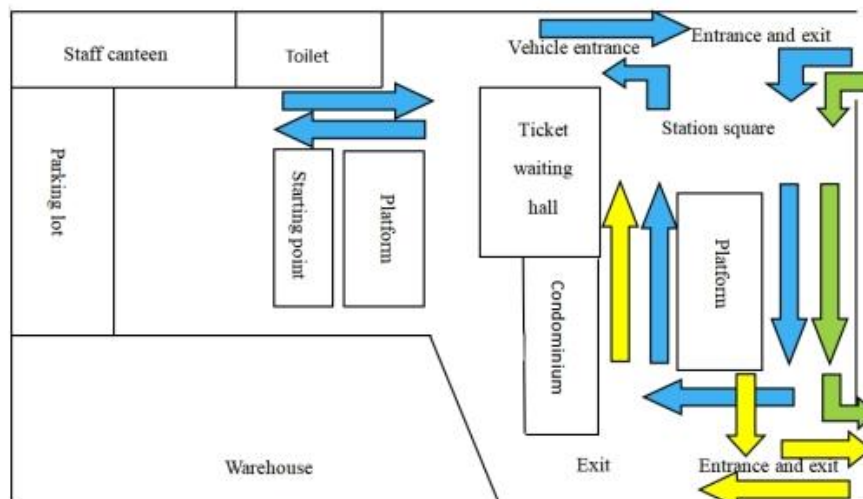


Figure 1. Overall layout Optimization Diagram
Source: (Li, 2021)

Information Dissemination

Clear signage and accessible facilities ensure a smooth passenger experience. Platforms for boarding and alighting should be spacious and adequately equipped to manage peak passenger volumes (Li, 2021). Real-time Information can provide passengers with real-time information on bus schedules, routes, delay times, and bus locations. This information can be distributed through various platforms such as bus terminal websites, mobile applications, television stations, radio stations, and directly at bus terminals and stops. This real-time data helps passengers make informed decisions and reduces uncertainty during their journey. Automation and real-time updates streamline operations and reduce manual effort, enhancing overall efficiency. Timely and accurate information, easy access to services, and a safe environment improve passenger satisfaction. Efficient resource utilisation and reduced need for manual interventions lead to cost savings for terminal operators. Using loudspeakers, electronic boards, and mobile notifications to inform passengers about delays and expected wait times helps manage expectations and reduces frustration. ICT solutions contribute to sustainability by reducing paper use, optimising energy consumption, and enhancing operational efficiency (Caroline Sutandi, 2019).

Safety Measure

S. Logeswaran et al. (2021) suggest that incorporating these safety measures in terminal design can lead to better traffic management, enhanced passenger safety, and improved overall transportation system efficiency in bus terminals. The implementation and maintenance of CCTV surveillance systems in major bus terminals improves the overall safety and security environment. This reassures passengers and helps in monitoring and managing crowd control, thereby ensuring smooth operations and enhancing user satisfaction (Sutandi, 2019).

Implementing correction factors allows terminal designs to address safety concerns by optimising the layout and structure of the terminal area, thereby reducing the risk of accidents and congestion (Logeswaran, et al., 2021). Overall, a good implementation of safety measures' reliability in a bus station gains passenger trust.

User Experience

According to Norhidayu (2017), there are several factors influencing user experience at bus terminals. The factor that influences user experience in the terminal bus is facilities and services to substance the function in the bus terminal. Furthermore, accessibility and convenience of the user that inclusive to all people categories. Adequate and convenient parking options, including multi-storey car parks and parking spaces for disabled people, are important. Ease of parking and security of parked vehicles are also crucial. Cleanliness and maintenance of the terminal space, such as the waiting area and restroom. Regular maintenance of facilities to ensure the system functions in top condition. To gain reliability and trustworthiness of the User, Safety and Security are also important to ensuring that the terminal is safe and can handle emergencies efficiently, contributing to user confidence and comfort. In terms of Personal safety, the feeling of safety and security within the terminal, including well- lighting areas and the presence of security personnel, is a critical factor for users.

An information and Navigation system that provides availability of a clear and accessible information system for guiding users and providing updates about bus schedules and routes is essential. Proper signage and wayfinding aids within the terminal help users navigate easily and reduce confusion, enhancing overall user experience.

Furthermore, the layout and Design should be an ergonomic design. Design and layout of the terminal should be considered for user comfort, ease of movement and accessibility. An organised and well-planned layout can reduce walking distance and improve user experience. Sustainable design is also very important to implement the adaptability element in terminals to adapt to changes in user needs and an increase in user numbers over time to maintain its effectiveness and user experience (Norhidayu, 2017).

Integration of Electric Buses in Terminal Design

Integrating electric buses into terminal infrastructure represents a fundamental shift in how transport hubs are conceived and operated. Electric bus adoption introduces new spatial and technological requirements, including charging infrastructure, grid connectivity, and thermal management systems. According to UN-Habitat (2022), transport terminals can evolve into energy transition hubs, serving as both mobility centres and renewable energy microgrids. Efficient integration requires comprehensive planning of land use, electrical load management, and battery-charging logistics. Furthermore, Liu et al. (2024) stated that the shift towards electric buses has the potential to significantly diminish both the expenses associated with vehicle procurement and their operational expenditures. Through the strategic enhancement of bus service configurations and the optimisation of charging infrastructure, it is feasible to reduce the cumulative cost of the system, thereby rendering electric buses a more financially sustainable alternative for public transportation networks.

RESEARCH METHOD

Introduction

The methodology presented in this dissertation describes the critical success factor to analyse the attribute factor that influences the adoption of electric bus facilities with local intercity terminal bus design, with the purpose to support the low-carbon mobility blueprint 2021-2030 initiative, encouraging energy transition in public transportation. This investigation employs document analysis of bus terminal design strategy and a content analysis of secondary data according to the region plan strategy for the

success of electric bus infrastructure implementation in the terminal. The selection of each method aims to obtain a more comprehensive understanding of successful factor bus terminal design from different perspectives: terminal layout functionality, user experience and comfort, safety and locality with the integration of electric bus function. The selected literature should provide a wide variety of elements and principles, Operational structure and User experience that can improve the Bus Terminal with the integration of an electric vehicle facility for electric buses.

This study investigates the critical success factors (CSFs) for integrating electric buses (EBs) into bus terminal design, with a focus on sustainable architectural and operational frameworks. A systematic literature review was conducted using document and content analysis of secondary sources. The research aims to identify thematic design principles and operational strategies, translating these variable practices into a framework that can be adapted to the Malaysian context.

Research Design

The research involves a comprehensive exploration of the critical success factors for the adoption of electric buses in a bus terminal. It involves a systematic literature review and Thematic analysis based on the document, aligning with research exploratory to identify the critical success factors for the adoption of electric buses and bus terminal design that contribute to developing a conceptual adoption of electric buses in bus terminal design.

The methodology of this thematic review article was adapted from Zairul (2020). In the first step, a systematic research study is conducted to determine the current academic understanding of the critical Success factor for the adoption of electric buses in the bus terminal. Published publications were retrieved from Google Scholar, Scopus, Reports, guidelines and Web of Science, where available. The advanced research keyword list is presented in Tables 1 and 2 below. In addition, the Scopus AI engine by Copilot database was used to find publications containing the terms "Electric bus", "Bus Terminal Design" AND "Critical Success Factor" [2012 TO 2024]. When the findings of two databases were assessed, this resulted in around 75 articles.

This study focuses on critical success factor adoption for electric bus and bus terminal design. The software used to initiate the data collection of the critical success factor attribute is ATLAS. Ti 9. After importing all metadata into ATLAS. Ti 9, primary documents were generated. Several groupings were automatically constructed within the code group based on the Mendeley-established metadata. ATLAS.ti 9's categorisation has streamlined and simplified the sorting procedure.

Table 1. Database Search Term

Source	Search Term	Result
SCOPUS	Scopus AI engine search by Copilot "Electric Bus", "Bus terminal Design" and "Critical Success Factor", Year 2012 to 2024	20 Result
Google Scholar	"Electric Bus Adoption", Bus Terminal Design and "Critical Success Factor" Year 2012 to 2024	20 Result
Mendeley	"Electric Bus Adoption", "Bus Terminal Design" and "Critical Success Factor", Year 2012 to 2024	18 Result
Wos	"Electric Bus Adoption", "Bus Terminal Design" and "Critical Success Factor", Year 2012 to 2024	17 Result

Content Analysis through Systematic Literature Review

Content analysis in this context encompasses academic articles, strategy policy, reports of the electric bus adoption and examines to explore innovative sustainable techniques worldwide to come out with the code theme of successful electric bus adoption in the terminal. As part of the Systematic Literature Review, to analyse the strategy related to the integration of the electric bus adoption strategy using

Atlas. Ti 9 software to generate code and arrange based on the theme. This involves a compilation from the literature on the effective methodologies.

The study used the query function to retrieve public-related critical factors of electric bus-friendly terminal integration from the Research Database. Selection includes Scopus' extensive global coverage by using the AI engine by Copilot, which can be searched using normal terms of writing, its inclusion of a wide range of disciplines, its robust citation data, the presence of author and institutional profiles and its user-friendly data analysis feature. The query focused on terms such as 'Adoption of electric bus in current terminal', 'Factor influencing the implementation of electric buses and 'Electric Bus friendly Terminal design'. The most common types of publication were articles and conferences, while the least common type was of report review on a different region.

Inclusion and Exclusion Criteria in the Thematic Review

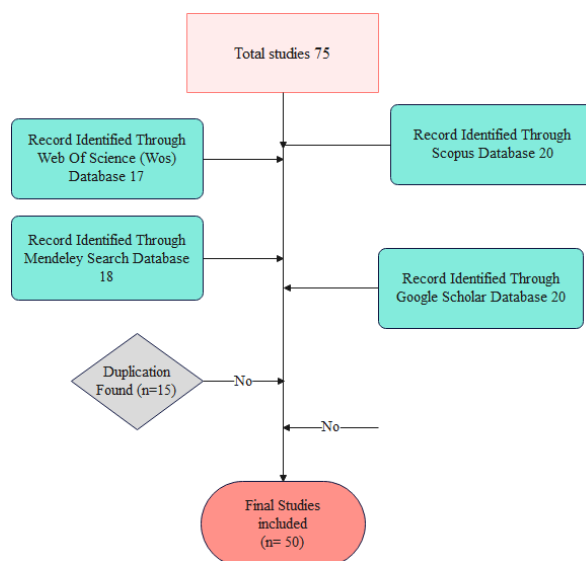


Figure 2. Inclusion and Exclusion Criteria in the Thematic Review.
Source: (Author, 2024)

Coding Analysis based on Systematic Literature Review Finding

Coding analysis was used to organise and synthesise the reviewed literature to gather recurring themes and critical success factors to adopt electric buses in bus terminal design. ATLAS.ti 9 software was used to code and categorise data; coding was streamlined and categorised further for a more thorough thematic analysis.

The coding analysis process was performed to sort and categorise data from the reviewed literature in a systematic way. All selected articles, reports and policy documents were imported to ATLAS.ti 9 software for coding and data organisation. The first step was to come up with preliminary codes generated from recurring keywords and themes observed in the literature. ATLAS.ti 9 software enabled the visualisation of code relationships, providing insights into the interconnections between themes.

Thematic Review Steps

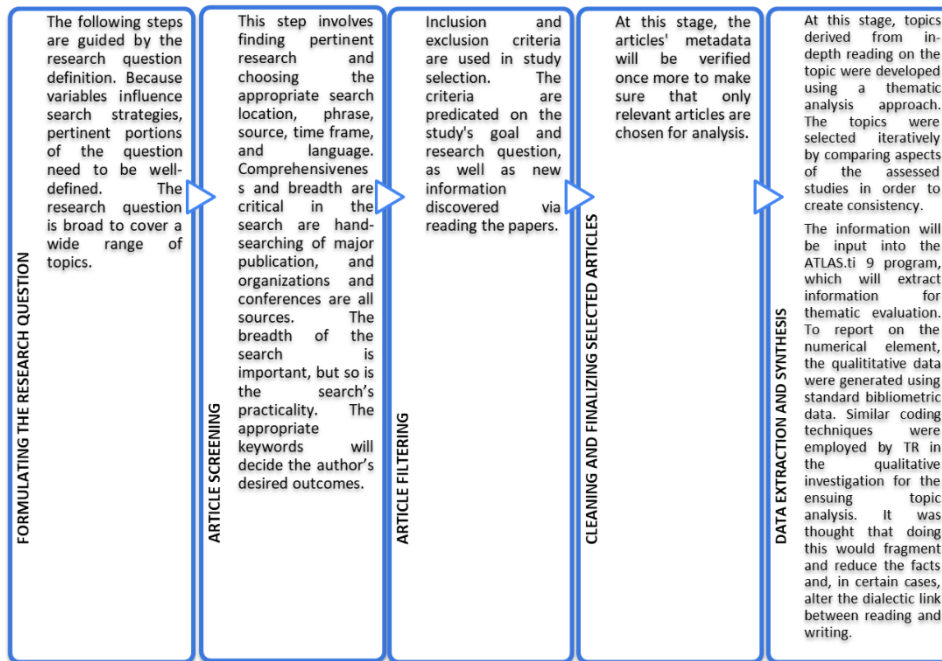


Figure 3. Thematic Review Steps
Source: (Author,2024)

Research Method Framework

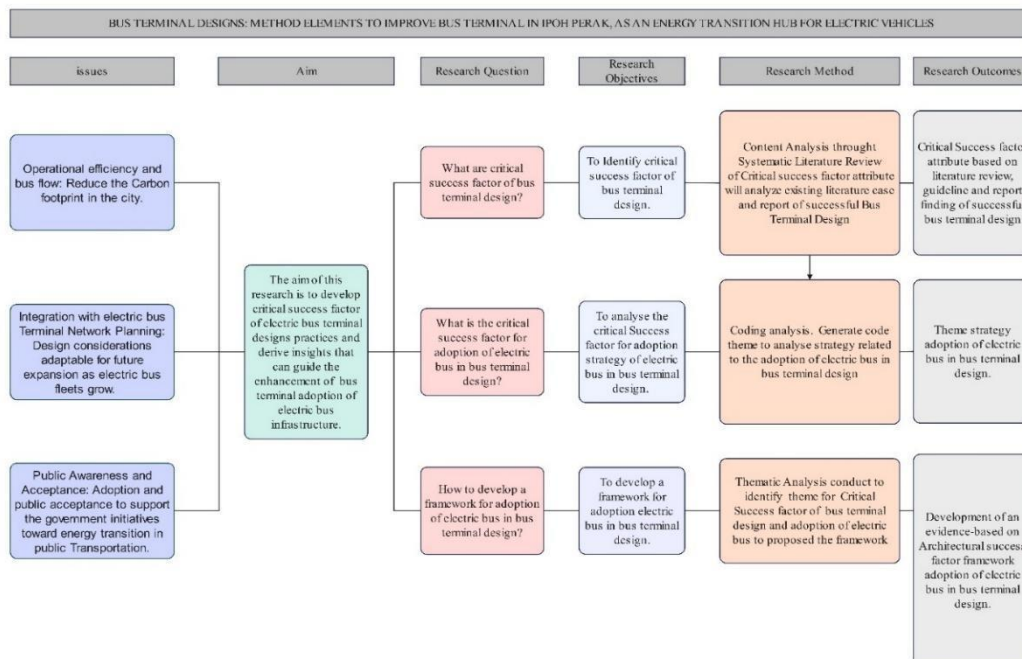


Table 2. Research methodology

Methodology	Sampling	Data Collection	Data Analysis	Outcomes
Content Analysis through Systematic Literature Review	Scholarly Sources	Content Analysis through Systematic Literature Review of Critical Success Factor attributes will analyse existing literature cases and reports of successful Bus Terminal Design.	To identify key design components of bus terminal design.	Critical Success Factor attribute based on literature review, guidelines and report findings of successful bus terminal design
Coding Analysis	Resourced from scholarly articles, journal articles, reports and websites	Coding Analysis strategy related to the adoption of the electric bus strategy	Comprehensive analysis code to generate a theme for the adoption of electric buses in bus terminal design	Critical success factor attribute strategy adoption of electric bus in bus terminal design.
Thematic Analysis	Critical Success factor of bus terminal design and adoption of electric bus theme finding	Thematic Analysis was conducted to identify themes for the Critical Success factors of bus terminal design and the adoption of electric buses, to propose a framework.	Thematic finding framework proposal	Development of an evidence-based Architectural success factor framework adoption of electric buses in bus terminal design.

RESULTS AND DISCUSSION

The transition to sustainable and inclusive public transportation plays a crucial role in finding solutions for global challenges such as urban congestion, environmental degradation, and accessibility disparities. It is in this context that the study adds to the literature on the identification of Critical Success Factors (CSFs) for bus terminal design, emphasising efficient, user-oriented, and environmentally friendly transportation systems.

These further underlines that bus terminals are critical nodes within urban transport infrastructure, with the growing adoption of electric buses. By examining the adoption of electric vehicles (EVs) in the design of bus terminals, this research highlights their important role to adapt with energy transition hubs supporting both transportation needs and renewable energy goals.

The results of this study are particularly relevant considering the global shift toward zero-emission mobility and the increasing demand for accessible public transportation. Policymakers, urban planners, and transport stakeholders can leverage these insights to inform the development of improved terminal designs, streamline the introduction of electric buses, and establish a framework that balances operational efficiency, sustainability, and user satisfaction.

Thus, this research bridges the gap between theoretical principles and practical implementation, offering comprehensive insights into how bus terminals can drive sustainable urban mobility and the energy transition.

This thematic analysis presented an overview of the Critical success factors of the Bus terminal and the critical Success factor adoption of the Electric bus in the bus terminal for sustainable transformation in the public transportation system. The articles chosen revealed several Critical Success Factors (CSFs) that play a pivotal role in shaping successful public transport systems. These CSFs span key areas such as accessibility, infrastructure design, sustainability, policy & governance, safety & security, and the adoption of electric vehicles (EVs).

Critical Success Factor: Adoption of Electric Bus in Bus Code Source and Theme

Next, the paper identified themes of concern to academics using the Critical success factors of adopting electric buses in the Bus Terminal. 7 themes, namely F1 (Infrastructure Readiness), F2 (Environmental Sustainability), F3 (Technology Integration), F4 (Policy and Financial Support), F5 (Passenger Experience), F6 (Operational Efficiency) and F7 (Stakeholder Collaboration), specifically identified from the articles examined following the study's focus topic or endogenous factors (Table 3). It should be noted that the Critical success factor of bus terminal design and the factor adoption of electric buses in transportation.

Table SEQ Table * ARABIC 4. CSF of Adoption Electric Bus in Bus Terminal Design Code and Theme

Source	Passenger Experience								Operational Efficiency								Stakeholder Collaboration								
	1E	2E	3E	4E	5E	6E	7E	8E	1F	2F	3F	4F	5F	6F	7F	8F	1G	2G	3G	4G	5G	6G	7G	8G	9G
Code																									
Rex Deighton-Smith et al. (2024)																									
Jamei et al. (2022)																									
Zareba et al. (2019)																									
Curtis et al. (2019)																									
(ESCAP) United Nations Economic and Social Commission for Asia and the Pacific (2024)																									
Yin Mun et al. (2019)																									
Deichmann (2021)																									
Stasiak-Cieslak & Grabarek (2023)																									
Göker & Hergül (2021)																									
Rodrigues et al. (2023)																									
Noegroho et al. (2021)																									
Lin et al., (2019)																									
Logeswaran et al. (2021)																									
Kuys et al. (2022)																									
Avenali et al. (2024)																									
Limpasirisuwan et al. (2024)																									
Ustadi & Shopi (2016)																									
R et al. (2024)																									
Lyu et al. (2019)																									
Ana Terra et al. (2023)																									
Lopez & Gorosabel (2017)																									
An (2020)																									
Pandey et al. (2024)																									
Yao et al. (2012)																									
Manzoli et al. (2022)																									
Su & Sze (2022)																									
Cirella et al. (2019)																									
Lalli et al. (2024)																									
Cairand et al. (2022)																									
Diez & Restrepo (2021)																									
Frank et al. (2021)																									
Ahmad et al. (2024)																									
Hamurcu & Eren (2020)																									
Hussain & Ramdan (2020)																									
Gromule et al. (2017)																									
Liu et al. (2019)																									
Olsson et al. (2021)																									
J. Ahmad et al. (2021)																									
May et al. (2017)																									
Stasiak-Cieslak & Grabarek (2023)																									
Aarhaug & Elvebakk (2015)																									
Srinivasa (2024)																									

CRITICAL SUCCESS FACTOR OF BUS TERMINAL DESIGN

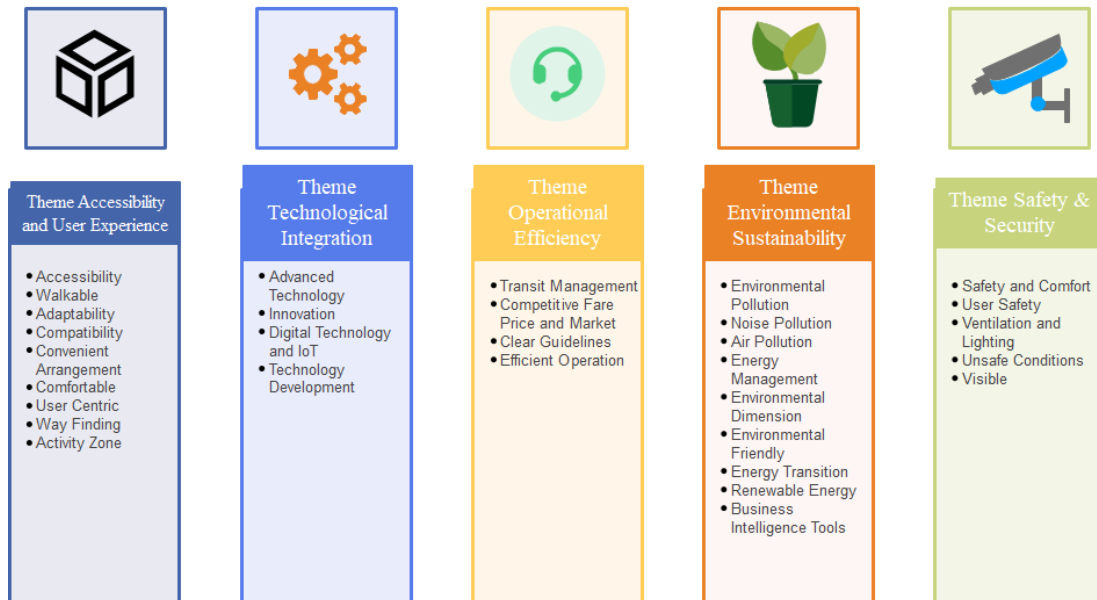


Figure 6. Theme Finding for Bus Terminal Design
Source: (Author, 2025)

CRITICAL SUCCESS FACTOR OF ADOPTION OF ELECTRIC BUS IN BUS TERMINAL

The design of bus terminals that support the integration of electric buses (EBs) highlights several critical success factors (CSFs) essential for advancing sustainable urban mobility. Key accessibility features—such as tactile surfaces, ramps, and real-time information systems ensure inclusivity, improve user experience, and encourage greater public transport usage. Infrastructure readiness is also vital, requiring modular terminal layouts and the availability of fast-charging stations to accommodate future demand and evolving technologies. Environmental sustainability is achieved through the incorporation of renewable energy sources and eco-friendly building materials, reducing both environmental impact and long-term operational costs in alignment with Malaysia’s Low-Carbon City initiatives. Technological integration, such as IoT-enabled systems, digital monitoring, and automated scheduling, further enhance operational efficiency and elevates passenger satisfaction. Policy and financial support, including government subsidies and public-private partnerships, are critical in overcoming the high upfront costs associated with electric bus infrastructure. Clear regulatory frameworks also help foster investor confidence and drive innovation. Operational efficiency is ensured through effective fleet management and optimised energy usage, while comprehensive safety measures, such as surveillance and emergency systems, help create secure environments that build public trust. Finally, strong stakeholder collaboration involving government agencies, private sector partners, and local communities ensures the alignment of interests and fosters innovation. Together, these factors enable the successful development of electric bus-friendly terminals that support Malaysia’s low-carbon mobility goals and contribute to a more sustainable urban future.

Critical Success Factor for Adoption of Electric Bus in Bus Terminal Design

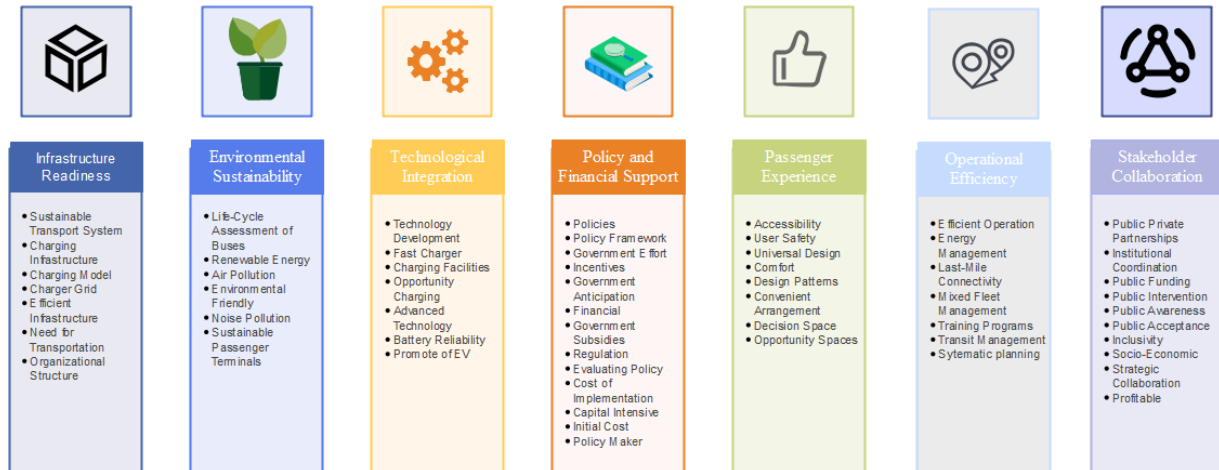


Figure 7. Theme Finding for the Adoption of Electric Bus in Bus Terminal Design
Source: (Author, 2025)

CONCLUSIONS

The results were organised into structured thematic categories aligned with the research objectives, using an iterative process to refine and validate the themes for accuracy and consistency. These themes were evaluated against existing frameworks and best practices to ensure their relevance and applicability within the Malaysian context. The integration of eco-friendly materials and renewable energy sources was found to reduce operational costs while supporting Malaysia's Low-Carbon City agenda.

Technological advancements such as IoT-enabled systems, digital monitoring, and automated scheduling were shown to improve operational efficiency and enhance user satisfaction. Meanwhile, policy and financial support mechanisms, including subsidies and public-private partnerships, play a crucial role in overcoming high initial investment barriers. Operational efficiency, complemented by robust safety measures, helps foster public trust and encourages greater use of public transportation.

Furthermore, effective stakeholder collaboration among government bodies, private sector entities, and local communities ensures the alignment of interests and facilitates innovation. Collectively, these findings form a comprehensive framework to guide policymakers, urban planners, and key stakeholders in designing and implementing sustainable, efficient bus terminals that accelerate the transition to electric mobility and contribute to Malaysia's broader low-carbon development goals.



Figure 8 Show the conceptual/schematic architecture design applying the critical success factors.
Source: (Author, 2025)



Table 5. Critical Success Factor of Bus Terminal Design vs Critical Success Factor Adoption of Electric Bus Terminal Design (Author, 2025)

Critical Success Factor of Bus Terminal Design	Factor of Bus	Critical Success Factor: Adoption of Electric Bus in Terminal Design
Theme: accessibility and user experience	and user	Infrastructure Readiness
Theme technological integration		Technological Integration
Theme operational efficiency		Passenger Experience
Theme environmental sustainability		Environmental Sustainability
Theme safety & security		Operational Efficiency
		Policy and Financial Support
		Stakeholder Collaboration

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHORS' CONTRIBUTION

All authors contributed to the design of the research and the write-up. The data cleaning and tabulation were undertaken by University Teknologi MARA. All authors have read and approved the final manuscript.

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AVAILABILITY OF DATA AND MATERIALS

Data is openly available in a public repository, with a permanent identifier (such as a DOI).

DECLARATION OF GENERATIVE AI

During the preparation of this work, author(s) used CHATGPT/ DRAFT WRITING to enhance the clarity of the writing. After using the [STEALTH AI / GRAMMAR CHECKING], the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

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'Disokong. Pengecualian dari semakan etika' - JKK PENYELIDIKAN PASCASISWAZAH UiTM

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