THE DEVELOPMENT OF STRUCTURAL EQUATION MODELING OF SERVICE QUALITY AND INTENTION TO USE FOR REGIONAL PUBLIC TRANSPORTATION OF THE ELDERLY IN THAILAND

ANON CHANTARATANG

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Industrial and Logistics Management Engineering

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การพัฒนาแบบจำลองสมการโครงสร้างคุณภาพการให้บริการและความตั้งใจใช้ขนส่งสาธารณะในภูมิภาคของผู้สูงอายุในประเทศไทย

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อานนท์ จันทรตัง : การพัฒนาแบบจำลองสมการโครงสร้างคุณภาพการให้บริการและความตั้งใจใช้ขนส่งสาธารณะในภูมิภาคของผู้สูงอายุในประเทศไทย (THE DEVELOPMENT OF STRUCTURAL EQUATION MODELING OF SERVICE QUALITY AND INTENTION TO USE FOR REGIONAL PUBLIC TRANSPORTATION OF THE ELDERLY IN THAILAND) อาจารย์ที่ปรึกษา : รองศาสตราจารย์ ดร.สัจจากาจ จอมโนนเขวา, 165 หน้า.

คำสำคัญ: ผู้สูงอายุ/ขนส่งสาธารณะ/คุณภาพการให้บริการ/เจตนาเชิงพฤติกรรม/แบบจำลองสมการโครงสร้าง

วิทยานิพนธ์ฉบับนี้มุ่งศึกษาความคาดหวังด้านคุณภาพการให้บริการและเจตนาเชิงพฤติกรรมต่อการใช้ระบบขนส่งสาธารณะภูมิภาคของผู้สูงอายุในประเทศไทย ผ่านการวิเคราะห์สมการโครงสร้าง (Structural Equation Modeling) เชิงลึก 3 การศึกษา เพื่อทำความเข้าใจความต้องการด้านการเดินทางของผู้สูงอายุ ซึ่งถือเป็นปัจจัยสำคัญต่อการพัฒนาระบบขนส่ง สาธารณะที่ครอบคลุมและยั่งยืน

การศึกษาแรก มุ่งตรวจสอบความเท่าเทียมของการวัด (Measurement Invariance) ด้านความคาดหวังต่อคุณภาพการให้บริการขนส่งสาธารณะที่ยั่งยืน ระหว่างผู้สูงอายุในเขตเมืองและชนบท โดยใช้การวิเคราะห์ปัจจัยยืนยันลำดับที่สอง (Second-Order Confirmatory Factor Analysis) ข้อมูลจากผู้สูงอายุในภูมิภาคหลักของประเทศไทยสะท้อนให้เห็นความเท่าเทียมของการวัดใน 11 มิติของคุณภาพการให้บริการ ประกอบด้วย 9 มิติดั้งเดิม ได้แก่ ยานพาหนะ ป้ายรถโดยสาร การเข้าถึง ความสะดวกสบาย ข้อมูล บุคลากร ความปลอดภัยและความมั่นคง ความเชื่อถือได้ และความคุ้มค่า และ 2 มิติใหม่หลังการแพร่ระบาด ได้แก่ สิ่งอำนวยความสะดวกสำหรับผู้สูงอายุ และการป้องกันหลังการแพร่ระบาด โดยผลการศึกษาเน้นย้ำความสำคัญร่วมกันในมิติ “ความสะดวกสบาย” “บุคลากร” และ “ความเชื่อถือได้” ขณะที่ผู้สูงอายุในชนบทให้ความสำคัญมากกว่าในมิติ “ความปลอดภัยและความมั่นคง”

การศึกษาที่สอง มุ่งวิเคราะห์ปัจจัยกำหนดความภักดีของผู้โดยสารสูงอายุโดยใช้การวิเคราะห์สมการโครงสร้างจากข้อมูลผู้สูงอายุใน 5 ภูมิภาค ผลการศึกษาพบว่า “ความไว้วางใจ” “ความผูกพัน” และ “คุณค่าที่รับรู้” เป็นตัวทำนายที่สำคัญที่สุดของความภักดี โดยเฉพาะคุณภาพการบริการที่รับรู้ ซึ่งมีบทบาทสำคัญอย่างยิ่งในการสร้างความไว้วางใจ เส้นทางความสัมพันธ์ “คุณภาพการให้บริการ-ความไว้วางใจ-ความภักดี” จึงเป็นกลไกหลักในการพัฒนาความภักดีของผู้โดยสารสูงอายุ

การศึกษาที่สาม เปรียบเทียบเจตนาเชิงพฤติกรรมของผู้สูงอายุต่อการใช้ระบบขนส่งสาธารณะอัจฉริยะ ระหว่างเขตเมืองและชนบท โดยผสานกรอบแนวคิด Technology Acceptance Model (TAM) และ Theory of Planned Behavior (TPB) ผลการวิเคราะห์ชี้ว่า “การรับรู้ประโยชน์” เป็นตัวทำนายที่มีอิทธิพลสูงสุดต่อการก่อตัวของทัศนคติในทั้งสองบริบท ขณะที่ผู้สูงอายุในชนบทมีความอ่อนไหวมากกว่าในด้าน “การรับรู้ความง่ายในการใช้” ได้รับอิทธิพลทางสังคม “บรรทัดฐานเชิงอัตวิสัย” ที่มากกว่า และให้ความสำคัญต่อ “การรับรู้การควบคุมพฤติกรรม” มากกว่าผู้สูงอายุในเขตเมือง

โดยสรุป วิทยานิพนธ์ฉบับนี้ได้วางรากฐานเชิงประจักษ์สำหรับการพัฒนาระบบขนส่งที่เป็นมิตรต่อผู้สูงอายุ ซึ่งผสมผสานทั้งมิติคุณภาพการให้บริการดั้งเดิมและข้อกำหนดใหม่ภายหลังการแพร่ระบาด ผลลัพธ์จากการวิจัยมอบแนวทางสำคัญแก่ผู้ประกอบการด้านการขนส่ง ผู้กำหนดนโยบาย และนักพัฒนาเทคโนโลยี ในการสร้างระบบการเดินทางที่ครอบคลุมทุกช่วงวัย รองรับการเข้าสู่สังคมสูงวัยของประเทศไทย และสอดคล้องกับเป้าหมายด้านความยั่งยืน ขณะเดียวกัน กรอบการวัดและแบบจำลองพฤติกรรมที่ผ่านการตรวจสอบแล้ว ยังมีส่วนสำคัญต่อการพัฒนาองค์ความรู้เชิงทฤษฎีว่าด้วยพฤติกรรมการเดินทางของผู้สูงอายุในประเทศกำลังพัฒนาที่กำลังเผชิญการเปลี่ยนแปลงทางประชากรศาสตร์

สาขาวิชา <u>วิศวกรรมการจัดการอุตสาหกรรมและโลจิสติกส์</u>

ปีการศึกษา <u>2568</u>

ลายมือชื่อนักศึกษา ....

ลายมือชื่ออาจารย์ที่ปรึกษา ....

ANON CHANTARATANG : THE DEVELOPMENT OF STRUCTURAL EQUATION MODELING OF SERVICE QUALITY AND INTENTION TO USE FOR REGIONAL PUBLIC TRANSPORTATION OF THE ELDERLY IN THAILAND. THESIS ADVISOR : ASSOC. PROF. SAJJAKAJ JOMNONKWAO, Ph.D., 165 PP.

Keyword: Elderly/Public transportation/Service quality/Behavioral intentions/Structural equation modeling

This thesis investigates service quality expectations and behavioral intentions toward regional public transportation among Thailand's elderly population through three comprehensive structural equation modeling studies. To understand elderly mobility needs, a crucial factor in developing inclusive and sustainable public transportation solutions.

The first study examined measurement invariance of sustainable public transport service quality expectations between urban and rural older adults using second-order confirmatory factor analysis. Data from elderly respondents across Thailand's major regions revealed successful measurement invariance across eleven service quality dimensions, including nine traditional factors (Vehicle, Bus Stop, Accessibility, Convenience, Information, Staff, Safety and Security, Reliability, and Affordability) and two novel post-pandemic dimensions (Older's Facilities and Post-Pandemic Prevention). Universal priorities emerged for Convenience, Staff quality, and Reliability, while rural elderly demonstrated elevated importance for Safety and Security measures.

The second study investigated determinants of elderly passenger loyalty using structural equation modeling with data from elderly participants across five regions. Results identified passenger trust, passenger commitment, and perceived value as the strongest predictors of loyalty, with perceived service quality demonstrating exceptionally strong effects on trust formation. The service quality-trust-loyalty pathway emerged as the critical mechanism for loyalty development among elderly passengers.

The third study compared elderly behavioral intention toward smart public transportation between urban and rural contexts through integrated Technology Acceptance Model (TAM) and Theory of Planned Behavior (TPB) frameworks. Analysis revealed that perceived usefulness was the strongest predictor of attitude formation across both contexts, while rural elderly exhibited enhanced sensitivity to perceived ease of use, stronger social influence effects, and greater importance of perceived behavioral control compared to urban counterparts.

The thesis establishes empirical foundations for developing elderly-friendly transportation systems that accommodate both traditional service quality considerations and emerging post-pandemic requirements. Findings provide essential guidance for transportation operators, policymakers, and technology developers to create age-inclusive mobility solutions that effectively serve Thailand's aging society while achieving sustainability objectives. The validated measurement frameworks and behavioral models contribute to theoretical understanding of elderly transportation behavior in developing countries experiencing demographic transitions.

School of Industrial and Logistics Management Engineering

Academic Year 2025

Student's Signature ....

Advisor's Signature ....

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CHAPTER I

INTRODUCTION

1.1 Background

Thailand is undergoing a significant demographic transformation. In 2023, the elderly population (aged 60 and above) reached 13.2 million, or 19.97% of the total population. Projections indicate that this proportion will surpass 28%, marking the country's transition from an "Aged Society" to a "Super-Aged Society" (Department of Older Persons, 2024). This rapid transition positions Thailand as one of the fastest-aging societies in Southeast Asia, ranking second in ASEAN after Singapore with 22.96% elderly population (United Nations, 2023), This demographic change is fundamentally altering the nation's social structure and creating substantial challenges for public service provision, particularly in transportation systems.

This demographic shift presents critical implications for regional public transportation systems, which must adapt to meet the evolving mobility needs of an aging society while ensuring sustainable and inclusive transportation solutions (Ministry of Transport, 2020). Public transport plays a crucial role in maintaining the quality of life, independence, and social participation of older adults (Shrestha et al., 2017; Wong et al., 2018). However, current transportation utilization patterns among Thai elderly reveal significant challenges: private cars account for 23.63% of transport use, motorcycles for 27.86%, while public transit systems represent only 9.70% of their transportation choices (Champahom et al., 2020), These figures highlight the elderly population's limited intention and loyalty toward public transport. Consequently, enhancing ridership and fostering long-term engagement with public transit systems remain pressing challenges in addressing the mobility needs of Thailand's aging society.

The concept of service quality in public transport has evolved considerably, particularly in the post-pandemic context. As highlighted by Das and Pandit (2015), understanding user expectations is crucial for developing appropriate level-of-service benchmarks, especially in developing countries where service standards may differ from developed nations. Traditional service quality frameworks typically encompass tangible aspects such as vehicle conditions and infrastructure, as well as intangible elements including staff behavior and information provision (Zhang et al., 2019) (Jomnonkwao et al., 2020). However, for elderly passengers, specific attributes gain heightened importance, as Yuan et al. (2019) found that safety, convenience, and driver services are critical factors affecting their satisfaction with bus services. The COVID-19 pandemic has fundamentally altered public transport dynamics, introducing new considerations for service quality that extend beyond traditional parameters (Tirachini & Cats, 2020). For elderly passengers, who are particularly vulnerable to severe COVID-19 outcomes, enhanced hygiene protocols, physical distancing measures, and improved ventilation systems have become essential elements of perceived service quality (Chuenyindee et al., 2022).

The urban-rural divide in public transport service quality presents another layer of complexity in Thailand's transportation landscape, particularly affecting elderly populations who face distinct mobility challenges across different geographical contexts. Research by Ponrahono et al. (2016) identified significant disparities between urban and rural bus services in Malaysia, while studies in Thailand by Wisutwattanasak et al. (2023) demonstrated that railway service expectations vary significantly between urban and rural users in Thailand, with urban passengers prioritizing accessibility and service empathy, while rural users emphasize staff quality and pricing considerations. These disparities become particularly pronounced when considering the elderly population's specific transportation needs, as rural elderly often encounter longer distances to transport nodes, limited-service coverage, and reduced exposure to digital technologies compared to their urban counterparts.

Furthermore, Thailand's transition toward digitalized transportation systems presents both opportunities and challenges for elderly populations across different geographical contexts (Elassy et al., 2024; Zhou et al., 2020). The implementation of smart public transport initiatives, including integrated technological systems with real-time information, digital payment methods, and automated scheduling, requires careful consideration of elderly users' technology acceptance patterns. Research reveals that physical limitations, cognitive changes, reduced confidence with digital interfaces, and limited prior technology exposure can significantly influence elderly individuals' willingness to adopt smart public transport services (Al-Rashid et al., 2021; Sun et al., 2020; Yu et al., 2024). This technological divide is particularly evident when comparing urban and rural contexts, where infrastructure disparities and varying levels of digital literacy create distinct patterns of technology acceptance among elderly populations, necessitating differentiated approaches to service design and implementation strategies that accommodate the diverse needs of Thailand's aging society across geographical boundaries.

The measurement of service quality expectations and behavioral intentions has gained prominence in transportation research, particularly through the application of structural equation modeling approaches. Early foundational work by the Transportation Research Board (1999) established the importance of understanding passenger expectations as a critical component of service quality assessment in public transportation systems. The expectation-confirmation theory, as applied by Fu et al. (2018) in their study of public transit loyalty, provides a robust framework for understanding how expectations shape satisfaction and subsequent behavioral intentions. These methodologies enable comprehensive examination of complex relationships between service quality dimensions, user expectations, satisfaction levels, and behavioral intentions toward public transport utilization, which becomes crucial for developing appropriate service standards and implementation strategies that effectively serve aging populations while achieving sustainable transportation objectives.

1.2 Purpose of the research

1) To develop a comprehensive service quality measurement framework that incorporates traditional dimensions and post-pandemic considerations for elderly passengers.
2) To examine the measurement invariance of sustainable public transport service quality expectations between urban and rural older adults using confirmatory factor analysis and multigroup analysis.
3) To investigate the determinants of elderly passenger loyalty in Thailand's public transportation using structural equation modeling.
4) To compare elderly passengers' behavioral intentions to use smart public transportation between urban and rural areas using structural equation modeling and multigroup analysis.

1.3 Scope of the research

1) The study population consists of elderly individuals aged 60 years and above across Thailand's major regions, categorized into young-old (60-69 years), middle-old (70-79 years), and oldest-old (80 years and above) groups.
2) The geographical coverage includes both urban and rural contexts across Thailand, with a focus on variations in service quality and behavioral differences in public transportation usage.
3) The public transportation systems examined encompass the predominant modes of transport utilized within each regional context, focusing on locally established and widely accessible transit services that serve as primary mobility options for elderly passengers in their respective areas.
4) The analytical approach employs structural equation modeling combined with multigroup analysis, in which measurement invariance across urban and rural contexts is examined based on infrastructure and basic activity facilities.

1.3.1 Urban and rural contexts definitions

For this research, urban and rural classifications are determined based on respondents' residential locations, following Thailand's official administrative and infrastructure criteria:

Urban areas are defined as municipalities and special administrative areas that demonstrate high population density, comprehensive public infrastructure development, and diverse economic activities. These areas typically feature integrated public transportation networks, including multiple transit modes such as rail systems, bus rapid transit (BRT), and conventional bus services with established route coverage and regular service frequencies. Urban contexts in this study encompass provincial capitals, major cities, and densely populated districts where residents have access to well-developed transportation infrastructure and digital connectivity.

Rural areas are characterized as non-municipal administrative zones (Tambon Administrative Organizations) with lower population density, agricultural-based economic activities, and limited public infrastructure. Public transportation in rural contexts typically relies on conventional bus services, songthaews (shared taxis), or informal transit modes with less frequent service schedules and limited route coverage. Rural elderly populations in these areas often face longer distances to transportation nodes, reduced service accessibility, and lower exposure to digital technologies compared to their urban counterparts.

1.3.2 Public transportation definitions

Current public transportation in this study encompasses the predominant transit modes utilized within each regional context, focusing on locally established and widely accessible services that serve as primary mobility options for elderly passengers. In urban areas, this includes bus rapid transit (BRT) systems, conventional urban bus services, and integrated multimodal systems. In rural contexts, current public transportation primarily consists of conventional bus services, songthaews, and other locally prevalent transit modes that connect communities to essential services and facilities.

Smart public transportation refers to technology-enhanced transit systems that integrate digital innovations to improve service delivery, operational efficiency, and user experience. Key characteristics of smart public transportation include:

1) Real-time information systems provide route updates, arrival predictions, and service disruptions through digital displays and mobile applications.
2) Integrated digital payment methods enabling cashless transactions through electronic ticketing, contactless cards, and mobile payment platforms.
3) Automated scheduling and route optimization systems utilizing data analytics for improved service reliability.
4) Intelligent transportation management systems incorporating GPS tracking, passenger counting, and fleet monitoring technologies.
5) User-friendly digital interfaces are designed to facilitate access to transportation information and services.

1.4 Research questions

1) What service quality dimensions influence elderly passengers' expectations toward sustainable public transport in Thailand?
2) Does the service quality measurement model remain invariant across urban and rural elderly populations?
3) What factors determine elderly passenger loyalty in Thailand's public transportation system?
4) How do urban and rural elderly differ in their behavioral intention to use smart public transportation?
5) Which factors best predict elderly behavioral intention toward smart public transport adoption?

1.5 Contribution of the research

1) Extends measurement invariance testing to elderly-specific service quality frameworks in developing country contexts while examining post-pandemic service quality dimensions as potential components of sustainable transport planning.
2) Investigates key factors influencing passenger loyalty among elderly users through comprehensive examination of service quality dimensions and behavioral determinants in public transportation contexts.
3) Develops comprehensive analytical frameworks to examine behavioral intention patterns and adoption factors among elderly populations in smart and sustainable transportation contexts.
4) Provides empirical foundations for national and regional policy development addressing elderly mobility needs through comparative analysis of urban and rural transportation contexts in aging societies.

1.6 Overview of the Study

The structure of this thesis consists of five chapters:

Chapter I: Introduction. This chapter presents the research background on Thailand's demographic transformation and establishes the research purpose, scope, questions, and contributions.

Chapter II: Measurement Invariance of Expectations toward Sustainable Public Transport Service Quality between Urban and Rural Older Adults in Thailand.

Chapter III: Determinants of Elderly Passenger Loyalty in Thailand's Public Transportation: A Post-Pandemic Perspective.

Chapter IV: A Comparison of Elderly Intention to Use Smart Public Transportation between Urban and Rural Areas in Thailand: An Integrated TAM–TPB Model.

Chapter V: Summary of the three studies, Conclusion, and Recommendations.

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CHAPTER II
MEASUREMENT INVARIANCE OF EXPECTATIONS TOWARD SUSTAINABLE PUBLIC TRANSPORT SERVICE QUALITY BETWEEN URBAN AND RURAL OLDER ADULTS IN THAILAND

2.1 Abstract

This study examines measurement invariance of expectations toward sustainable public transport service quality between urban and rural older adults in Thailand using second-order confirmatory factor analysis. Data were collected from 1,189 elderly respondents across Thailand's four major regions through face-to-face interviews. The measurement framework incorporated eleven service quality dimensions: nine traditional attributes (Vehicle, Bus Stop, Accessibility, Convenience, Information, Staff, Safety and Security, Reliability, and Affordability) and two extended dimensions specific to elderly populations (Older's Facilities and Post-Pandemic Prevention). Results demonstrated successful measurement invariance, confirming that the eleven-factor structure operates equivalently across urban and rural contexts. Universal priorities emerged for Convenience, Staff quality, and Reliability across both contexts, while rural elderly showed elevated importance for Safety and Security compared to urban counterparts. The validation of Older's Facilities and Post-Pandemic Prevention as distinct dimensions establishes empirical support for incorporating age-inclusive design and health protection measures as permanent components of sustainable transport planning. These findings justify unified national standards for elderly-friendly sustainable transport while accommodating regional variations, providing essential guidance for developing sustainable public transport systems that effectively serve aging populations while achieving environmental sustainability objectives.

2.2 Introduction

The global phenomenon of population aging has become increasingly prominent, particularly in developing countries where rapid demographic transitions are occurring. Thailand exemplifies this trend, with the elderly population (aged 60 and above) reaching 13.2 million or 19.97% of the total population in 2023, and projections indicating this will exceed 28% by 2040 (Department of Older Persons, 2024). This demographic shift presents significant challenges for public transportation systems, which must adapt to meet the evolving needs of an aging society while ensuring sustainable and inclusive mobility solutions (Ministry of Transport, 2020).

Public transport plays a crucial role in maintaining the quality of life, independence, and social participation of older adults (Shrestha et al., 2017; Wong et al., 2018). However, the COVID-19 pandemic has fundamentally altered public transport dynamics, introducing new considerations for service quality that extend beyond traditional parameters. The United Nations (2021) emphasized that sustainable transport systems must now incorporate pandemic prevention measures while maintaining accessibility for vulnerable populations, particularly older adults who face heightened health risks.

The concept of service quality in public transport has evolved considerably, with researchers employing various frameworks to assess user satisfaction and expectations. Zhang et al. (2019) utilized structural equation modeling to evaluate passenger satisfaction in urban rail transit, while Jomnonkwao et al. (2020) applied importance-performance analysis to intercity rail services. These studies consistently highlight that service quality is multidimensional, encompassing tangible aspects such as vehicle conditions and infrastructure, as well as intangible elements including staff behavior and information provision. For elderly passengers, specific attributes gain heightened importance, as Yuan et al. (2019) found that safety, convenience, and driver services are critical factors affecting their satisfaction with bus services. The urban-rural divide in public transport service quality presents another layer of complexity in developing countries. Ponrahono et al. (2016) identified significant disparities between urban and rural bus services in Malaysia, while studies in Thailand by Champahom et al. (2025) revealed that elderly passengers in rural areas face unique challenges related to accessibility and service availability. Recent research has increasingly recognized the heterogeneity in service quality perceptions among different user groups. Wisutwattanasak et al. (2023) demonstrated that railway service expectations vary significantly between urban and rural users in Thailand, with urban passengers prioritizing accessibility and service empathy, while rural users emphasize staff quality and pricing.

The measurement of service quality expectations, rather than just perceptions, has gained prominence in transport research. Early foundational work by the Transportation Research Board (1999) established the importance of understanding passenger expectations as a critical component of service quality assessment in public transportation systems. As highlighted by Das and Pandit (2015), understanding user expectations is crucial for developing appropriate level-of-service benchmarks, especially in developing countries where service standards may differ from developed nations. The expectation-confirmation theory, as applied by Fu et al. (2018) in their study of public transit loyalty, provides a robust framework for understanding how expectations shape satisfaction and subsequent behavioral intentions. The COVID-19 pandemic has introduced unprecedented challenges for public transport systems worldwide, necessitating fundamental changes in service delivery, including enhanced hygiene protocols, physical distancing measures, and improved ventilation systems (Tirachini & Cats, 2020). For elderly passengers, who are particularly vulnerable to severe COVID-19 outcomes, these pandemic-related modifications have become essential elements of perceived service quality, representing a critical evolution in transport research (Chuenyindee et al., 2022). Furthermore, sustainable public transport has expanded beyond environmental considerations to encompass social sustainability through inclusive design for aging populations. The United Nations (2021) emphasizes that post-pandemic recovery presents opportunities to incorporate universal design principles and age-friendly features, including priority seating, improved lighting, accessible information systems, and assistance services.

Despite growing research on public transport service quality, significant gaps remain in understanding how expectations toward sustainable service quality differ between urban and rural older adults, particularly in the post-pandemic context. Most existing studies have focused on either urban or rural contexts in isolation, without addressing elderly population's unique needs following COVID-19. Moreover, the incorporation of pandemic prevention measures and specialized facilities for older adults as distinct service quality dimensions has received limited attention in the literature. This study addresses these gaps by employing second-order confirmatory factor analysis to examine measurement invariance of sustainable public transport service quality expectations between urban and rural older adults in Thailand. The model incorporates eleven key attributes: nine traditional dimensions (Vehicle, Bus Stop, Accessibility, Convenience, Information, Staff, Safety and Security, Reliability, and Affordability) and two novel post-pandemic dimensions (Older's Facilities and Post-Pandemic Prevention). By testing measurement invariance, this research determines whether service quality conceptualization operates consistently across urban-rural contexts, providing essential insights for developing targeted strategies to enhance public transport services for Thailand's aging population.

The significance of this research extends to practical implications for transport planning and policy. As Thailand experiences rapid population aging alongside urban-rural development disparities, understanding how elderly citizens in different geographical contexts prioritize sustainable public transport service quality becomes crucial for equitable mobility solutions. This study's findings will inform evidence-based strategies for improving public transport services that meet diverse elderly needs while contributing to sustainable development and social inclusion goals (Department of Older Persons, 2024; Ministry of Transport, 2020).

2.3 Literature review

2.3.1 Traditional service quality

The conceptualization of service quality in public transport has evolved from broader service marketing theories, with the SERVQUAL model serving as a foundational framework. Zeithaml et al. (1993) established three types of customer service expectations: desired, adequate, and predicted service, with a zone of tolerance between desired and adequate levels. Building on this foundation, Parasuraman et al. (1993) developed the service quality framework, demonstrating that quality emerges from the gap between expectations and perceptions across five core dimensions: reliability, responsiveness, assurance, empathy, and tangibles. This framework has been extensively adapted for public transport contexts (Barabino et al., 2012).

In the public transport domain, traditional service quality attributes have been consistently identified across numerous studies. De Oña and De Oña (2015) emphasized that traditional attributes typically encompass punctuality, comfort, cleanliness, and safety, while Bakar et al. (2022) confirmed through their systematic review of 41 Asian bus service studies that 13 key attributes including frequency, on-time performance, reliability, comfort, and safety are most critical. These core attributes form the foundation of service quality assessment, as confirmed by Ojo (2019) who identified reliability, punctuality, affordability, and cleanliness as the most frequently cited factors across 85 reviewed articles. Additionally, Chaisomboon et al. (2020) revealed through multiple analytical approaches that safety equipment and service reliability are paramount concerns across all demographic groups.

The traditional service quality framework encompasses nine fundamental attributes consistently validated across diverse contexts:

Vehicle: Vehicle characteristics directly impact passenger comfort and safety perceptions. Barabino et al. (2012) identified cleanliness, air-conditioning, and spaciousness as critical attributes, while (Deb & Ali Ahmed, 2018) found vehicle condition among the most poorly rated factors in developing countries. Shen et al. (2016) demonstrated that modern features like low-floor designs serve as standard quality indicators, while Hadiuzzman et al. (2017) established that vehicle safety features significantly affect behavioral intentions.

Bus stop: Bus stop characteristics constitute critical touchpoints influencing accessibility and waiting comfort. Sun et al. (2020) found asymmetric effects of amenities like shelters and benches on satisfaction, with basic facilities significantly impacting dissatisfaction when absent. Sum et al. (2019) identified bus stop facilities as the most significant factor in Phnom Penh's system, while Wong et al. (2017) emphasized that stop conditions regarding cleanliness, lighting, and seating significantly influence overall satisfaction.

Accessibility: This encompasses both physical access and ease of system use. De Oña and De Oña (2015) emphasized spatial coverage, walking distance, and frequency as fundamental determinants, while Das and Pandit (2015) found significant differences in accessibility expectations between developed and developing nations. Güner (2018) demonstrated that network connectivity critically influences perceptions, while Lin and Cui (2021) emphasized context-specific requirements for aging populations.

Convenience: These attributes relate to ease and efficiency of service use. Esmailpour et al. (2020) identified convenience as one of four principal components encompassing boarding ease and intermodal connections, while Li et al. (2020) demonstrated that intelligent information services significantly enhance perceived quality. (Too & Earl, 2010) found transfer convenience substantially influences journey satisfaction, while Wisutwattanasak et al. (2023) revealed different convenience prioritization between urban and rural users.

Information: Information provision has emerged as crucial in the digital age, significantly influencing passenger confidence. Wu et al. (2016) found timely, accurate information reduces uncertainty and enhances reliability perceptions, while Zhou et al. (2019) demonstrated that information services before and during travel significantly influence transport choices. (Hounsell et al., 2016) noted elderly passengers prefer simple, clear displays over complex digital interfaces.

Staff: Staff behavior significantly influences service quality across all transport modes. Ratanavaraha and Jomnonkwao (2014) found driver skills primary concerns for safety, while Sinha et al. (2020) demonstrated that driver attitude significantly differentiates quality perceptions between systems. Joewono et al. (2016) established staff courtesy as particularly important for vulnerable passengers, while

Nguyen-Phuoc et al. (2021) found personnel quality significantly influenced loyalty intentions.

Safety and Security: These represent fundamental prerequisites encompassing traffic safety and personal security. Mandhani et al. (2023) identified these as high-priority aspects for elderly and disabled passengers, while Kacharo et al. (2022) found 50.8% of women experienced violence using public transport. van Lierop and El-Geneidy (2016) demonstrated that traffic safety significantly influences passenger confidence, while Kaewsopa and Fu (2024) emphasized elderly vulnerability requiring comprehensive safety measures including surveillance.

Reliability: Service reliability encompasses punctuality, consistency, and predictability. Redman et al. (2013) identified reliability as key for attracting car users, while Fu et al. (2018) found reliability had the strongest effect on loyalty through perceived quality. Cui et al. (2023) established reliability as the most critical factor for rural residents, while Wong et al. (2017) demonstrated waiting time as a significant satisfaction factor for elderly users.

Affordability: This remains fundamental, particularly in developing countries and for vulnerable populations. Zhang et al. (2019) demonstrated fare affordability significantly affected passenger satisfaction, while Sam et al. (2018) found users often accept lower quality when fares are subsidized. Value for money, rather than absolute fares, often determines satisfaction, with passengers evaluating fares relative to service quality and alternatives (Litman, 2016; Wong et al., 2018).

2.3.2 Extended service quality

Extended service quality dimensions encompass age-specific requirements including specialized facilities and health protection measures particularly prominent post-pandemic (Chuenyindee et al., 2022; Li et al., 2022). Recognition of older adults as distinct users with specific needs has led to two critical additional dimensions complementing traditional attributes: older adults' facilities and post-pandemic prevention measures, essential for inclusive systems serving aging populations (Mandhani et al., 2023; Tirachini & Cats, 2020).

Older’s facilities: Demographic shifts toward aging societies have prompted specialized facilities development. Wong et al. (2017) demonstrated seat availability as most critical for elderly satisfaction, while priority seating has evolved beyond designated seats to include ergonomically designed spaces. Shrestha et al. (2017) noted clear, high-contrast signage addresses age-related vision changes, while appropriate audio announcements accommodate hearing limitations. Yuan et al. (2019) found support feature availability significantly influenced elderly safety feelings, while Broome et al. (2013) found entry/exit ease prioritized above traditional attributes.

Post-pandemic prevention: COVID-19 has fundamentally transformed service quality requirements, introducing health measures as permanent attributes significantly influencing confidence. Tirachini and Cats (2020) identified visible health protection as key confidence factors for older adults facing higher risks, while Gkiotsalitis and Cats (2021) emphasized visible prevention measures directly impact perceived safety. Hsieh (2023) demonstrated epidemic prevention needs incorporated into safety assessment, while Ding et al. (2023) found pandemic prevention services significantly impact safety perception and satisfaction. Evidence from Taiwan shows lifting anti-epidemic measures may harm ridership recovery, as passengers prioritize safety over convenience (Hsieh & Hsia, 2022). Dong et al. (2021) found elderly users particularly prioritize control measure visibility including hand washing facilities and sanitization protocols, while Li et al. (2022) demonstrated comprehensive prevention measures significantly influence older adults' transport willingness.

Furthermore, this research has reviewed relevant literature on public transport service quality attributes among older adults, with particular attention to studies conducted during and after the pandemic (2019-Present). As shown in Table 2.1, the summary provides a comprehensive overview of these studies and indicates the presence or absence of each service quality attribute across various research contexts.

Table 2.1 Summary of previous studies on public transport service quality attributes among older adults (2019-Present)

Authors	Location / Mode	Method	Traditional service quality attributes									Extended service quality attributes	
			Vehicle	Bus Stop / Station	Accessibility	Convenience	Information	Staff	Safety & Security	Reliability	Affordability	Older's facilities	Post-pandemic prevention
This Study	**Thailand / Bus**	**Multigroup CFA**	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Khurshid and Othayoth (2024)	India / Bus	Probit model	✓	✓	✓	✓	-	-	✓	✓	✓	-	-
Mandhani et al. (2023)	India / Metro rail	IPA, SEM	-	✓	✓	✓	✓	✓	✓	-	-	✓	-
Wisutwattanasak et al. (2023)	Thailand / Rail Transport	SEM	✓	✓	-	✓	✓	✓	✓	✓	-	-	-
Lan et al. (2022)	China / Bus	IAA	✓	✓	-	✓	✓	✓	✓	✓	✓	-	-
Mariotti et al. (2021)	Italy / Local Public Transport	Logistic regression	-	-	-	-	✓	-	✓	✓	✓	-	-
Tavares et al. (2021)	Brazil / Bus	SEM	-	-	-	-	-	-	✓	✓	-	-	-
Chaisomboon et al. (2020)	Thailand / Bus	IPA / Gap analysis	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	-
Liu et al. (2020)	USA / Urban rail	Probit model	-	✓	✓	-	-	-	-	-	-	-	-
Lättman et al. (2019)	Europe / Public transport	SEM	-	-	✓	-	-	-	-	-	-	-	-
Yuan et al. (2019)	China / Bus	IPA, SEM	-	✓	✓	✓	✓	✓	✓	✓	✓	-	-
Cirella et al. (2019)	Global / Public transport	Systematic review of literature	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-

Note: "✓" means attributes that were included in the studies, IPA: Importance-Performance Analysis, IAA: Impact-Asymmetry Analysis, SEM: Structural Equation Modeling.

2.4 Methods

2.4.1 Questionnaire development

The research instrument was developed through a systematic multi-stage process combining extensive literature review and expert validation procedures. The questionnaire comprised two primary sections: (1) demographic characteristics and (2) sustainable service quality expectations. The core measurement framework incorporated eleven traditional service quality attributes included Vehicle (4 items), Bus Stop (4 items), Accessibility (3 items), Convenience (3 items), Information (3 items), Staff (4 items), Safety and Security (3 items), Reliability (4 items), and Affordability (3 items). Extended dimensions specifically relevant to elderly populations encompassed Older's Facilities (3 items) addressing visual/audio aids, handrails, and accessibility features, and Post-Pandemic Prevention (3 items) evaluating screening protocols, hygiene controls, and safety measures.

Content validity was rigorously assessed through expert evaluation involving five subject matter experts in public transportation who applied the Index of Item Objective Congruency (IOC) methodology to evaluate each measurement item. Only questions achieving an IOC score above 0.50 were retained in the final instrument, ensuring that all items demonstrated acceptable content relevance and alignment with the research objectives (Lawshe, 1975). The instrument underwent pilot testing with 50 respondents to evaluate completion time and preliminary reliability estimates. All service quality items were measured using a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). The 7-point scale was selected for its optimal balance between measurement precision and respondent usability, offering superior discrimination over 5-point scales while avoiding the cognitive burden of longer scales that may overwhelm elderly respondents with excessive options (Joshi et al., 2015). The final instrument demonstrated excellent internal consistency reliability across all constructs, with Cronbach's alpha coefficients ranging from 0.804 to 0.915, as presented in Appendix 2.1 alongside comprehensive statistical summaries for all measurement variables.

2.4.2 Data collection and validation

Data collection was conducted between February and March 2024 using a comprehensive stratified sampling framework designed to capture representative perspectives from diverse geographical and socioeconomic contexts across Thailand. The sampling strategy targeted elderly participants aged 60 years and above who possessed previous experience using regional public transportation services, ensuring that respondents had practical knowledge of existing transport systems that could inform their expectations regarding sustainable service enhancements (Alsnih & Hensher, 2003; Sam et al., 2018). The geographical stratification encompassed Thailand's four major regions - Northern, Southern, Central, and Northeastern - with provincial selection criteria prioritizing locations that maintained established public transportation infrastructure serving both urban and rural populations. This strategic selection enabled meaningful comparison of elderly expectations across varying levels of transportation service development and accessibility, reflecting the diversity of Thailand's transportation landscape from metropolitan areas with advanced transit systems to rural provinces with more limited service coverage.

Face-to-face interviews were administered by a team of trained research assistants specifically prepared to work with elderly populations and address potential challenges related to sustainable transportation terminology and conceptual understanding. Prior to questionnaire administration, research assistants provided carefully structured explanations of sustainable service quality attributes, including emerging bus technologies, accessibility features for older adults, and post-pandemic safety measures, ensuring that all participants possessed adequate conceptual understanding to provide informed responses. These explanatory sessions were designed to bridge potential knowledge gaps while avoiding leading or biasing participants' responses.

The data collection process strictly adhered to comprehensive ethical guidelines for research involving vulnerable populations, with the complete research protocol receiving formal ethical clearance from Suranaree University of Technology's Ethics Committee for Research Involving Human Subjects (COE No.3/2567). The interview protocol incorporated flexible pacing strategies to accommodate varying cognitive processing speeds and physical comfort needs, with each interview lasting approximately 20-30 minutes including consent procedures and conceptual explanations. The final validated sample comprised 1,189 respondents (631 urban, 558 rural) representing diverse socioeconomic backgrounds and transportation usage patterns across the four geographical regions, as detailed in Table 2.2, which provides comprehensive demographic characteristics including regional distribution alongside other key participant attributes.

Table 2.2 Demographic data

Characteristics	Category	Urban (n= 631)		Rural (n = 558)	
		Frequency	Percentage	Frequency	Percentage
Gender	Male	307	48.7%	266	47.7%
	Female	324	51.3%	292	52.3%
Status	Single	63	10.0%	36	6.5%
	Married	409	64.8%	385	69.0%
Age	60–69 years old	481	76.2%	429	76.9%
	70–79 years old	132	21.0%	115	20.6%
	≥ 80 years old	18	2.8%	14	2.5%
Education	Less than bachelor's degree	450	71.3%	489	87.6%
	Bachelor's degree	113	17.9%	45	8.1%
	Higher bachelor's degree	68	10.8%	24	4.3%
Occupation	Retired	137	21.7%	120	21.5%
	Government Employee	24	3.8%	17	3.0%
	Private Employee	51	8.1%	24	4.3%
	Business Owners	158	25.1%	102	18.3%
	Agriculturist	62	9.8%	178	31.9%
	General Laborer	188	29.8%	104	18.7%
	Other	11	1.7%	13	2.3%
Income	≤ 10,000 THB	323	51.2%	430	77.0%
	> 10,000 THB –20,000 THB	143	22.6%	67	12.0%
	> 20,000 THB –30,000 THB	107	17.0%	37	6.6%
	> 30,000 THB	58	9.2%	24	4.4%

Note: Sample size (N = 1,189).

2.4.3 Statistical methodology

2.4.3.1 Confirmatory factor analysis (CFA)

Confirmatory factor analysis was employed to evaluate the measurement model's validity and reliability for the eleven-factor structure of sustainable public transport service quality expectations. The CFA approach was selected over exploratory factor analysis due to the well-established theoretical foundation of service quality dimensions in public transport literature and the specific research objective of testing measurement invariance across geographical contexts (Brown, 2015). The analysis was conducted using maximum likelihood estimation with robust standard errors to accommodate potential deviations from multivariate normality, as recommended by Finney and DiStefano (2006) for survey data with Likert-scale responses.

The measurement model specification incorporated eleven first-order latent constructs representing traditional service quality attributes (Vehicle, Bus Stop, Accessibility, Convenience, Information, Staff, Safety and Security, Reliability, and Affordability) and extended dimensions specific to elderly populations (Older's Facilities and Post-Pandemic Prevention). Each latent construct was defined by three to four observed indicators, with factor loadings constrained to identify the model scale by fixing the first indicator loading to 1.0 for each construct. Error terms were assumed to be uncorrelated, consistent with the principle of local independence in factor analysis (Kline, 2015).

The CFA evaluation process encompassed three primary validation criteria: convergent validity, discriminant validity, and construct reliability. Convergent validity was assessed through examination of standardized factor loadings (target threshold ≥ 0.70), Average Variance Extracted (AVE ≥ 0.50), and Composite Reliability (CR ≥ 0.70), following guidelines established by Hair et al. (2019). Discriminant validity was evaluated using the Fornell-Larcker criterion, requiring that the square root of AVE for each construct exceed its correlations with other constructs (Fornell & Larcker, 1981). Internal consistency reliability was assessed through Cronbach's alpha coefficients, with values ≥ 0.70 indicating acceptable reliability (Nunnally, 1978).

2.4.3.2 Multigroup analysis

The multigroup confirmatory factor analysis framework was implemented to examine measurement invariance between urban and rural elderly populations, following the sequential testing procedure recommended by Vandenberg and Lance (2000) and Putnick and Bornstein (2016). This analytical approach enables systematic evaluation of whether the measurement instrument operates equivalently across different groups, ensuring that observed differences in latent means reflect true group differences rather than measurement artifacts (Milfont & Fischer, 2010).

The measurement invariance testing sequence proceeded through increasingly restrictive nested models: (1) configural invariance establishing equivalent factor structure across groups with all parameters freely estimated, (2) metric invariance constraining factor loadings to equality across groups, and (3) scalar invariance examining equality of item intercepts in addition to factor loadings (Steenkamp & Baumgartner, 1998).

The analytical framework incorporated maximum likelihood estimation to accommodate the complex survey design. This estimation method assumes multivariate normality of observed variables and provides efficient parameter estimates when distributional assumptions are reasonably met. Distributional properties were examined through assessment of skewness and kurtosis statistics prior to model estimation (Kline, 2015).

2.5 Data analysis

This section presents the analytical results based on the systematic research procedure shown in Figure 2.1 The analysis commenced with comprehensive data preparation including data cleaning, validation, and normality assessment, followed by confirmatory factor analysis to evaluate each measurement model's convergent validity, internal consistency, and model fit. Subsequently, second-order confirmatory factor analysis was conducted for individual groups (urban and rural) to examine the hierarchical structure of service quality expectations. Finally, measurement invariance testing was performed through simultaneous modeling and factor loading constraints to assess measurement equivalence across groups. The analytical framework employed both SPSS 29.0 for descriptive statistics and Mplus 7.2 for confirmatory factor analysis, with maximum likelihood estimation ensuring robust parameter estimates and model evaluation.

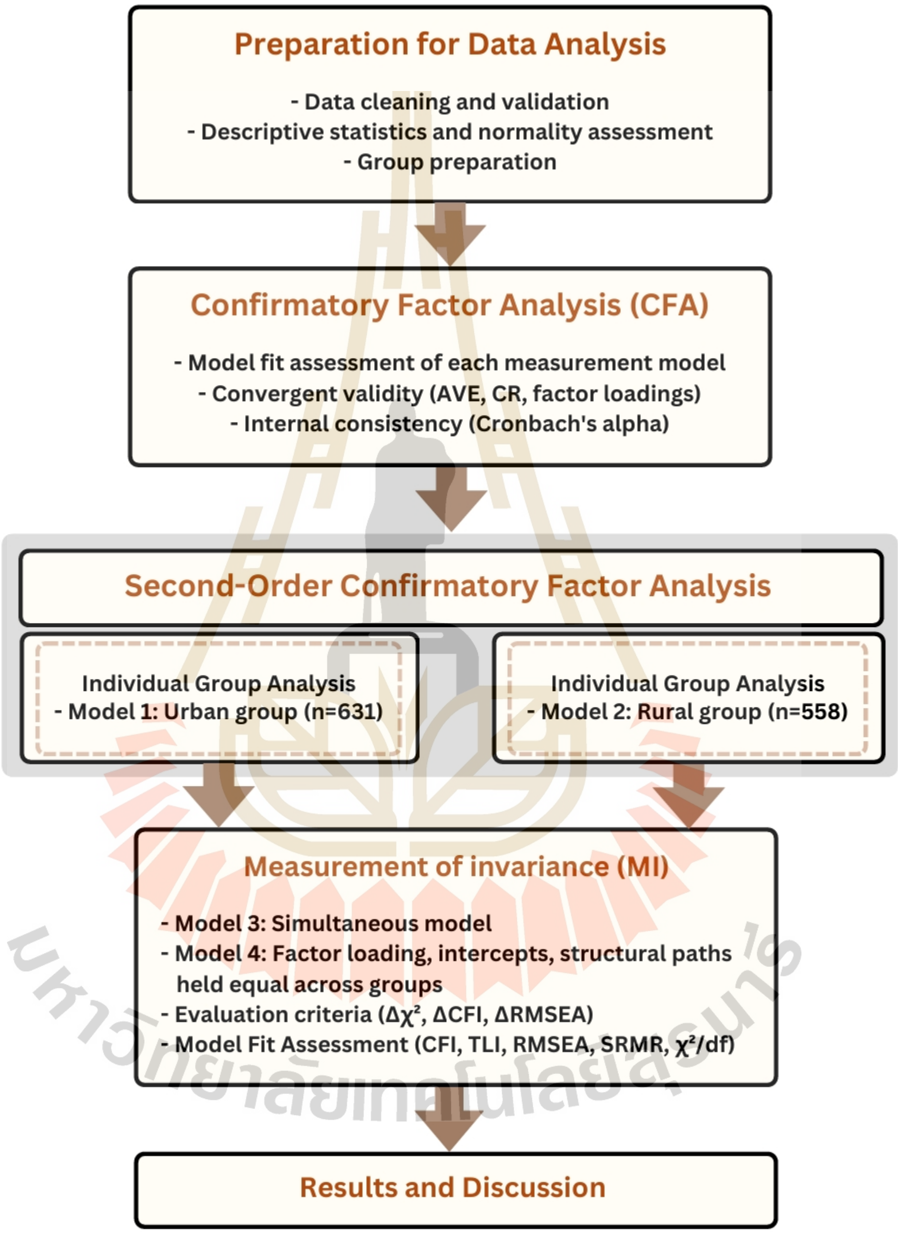

Figure 2.1 Research procedure

2.5.1 Descriptive analysis

Table 2.2 presents the final validated sample comprising 1,189 elderly respondents, including 631 from urban areas (53.1%) and 558 from rural areas (46.9%). The table shows comprehensive demographic characteristics with balanced representation across key variables. Gender distribution was relatively even, with females comprising 51.3% of urban participants and 52.3% of rural participants. Age distribution showed concentration in the 60-69 years category, representing 76.2% of urban and 76.9% of rural respondents, while participants aged 70 years and above constituted approximately 24% of both groups. Educational attainment varied between urban and rural contexts, with 71.3% of urban participants and 87.6% of rural participants holding less than bachelor's degree qualifications. Occupational patterns differed notably, with urban areas showing higher proportions of business owners (25.1%) and general laborers (29.8%), while rural areas demonstrated greater representation of agriculturists (31.9%). Income distribution reflected geographical disparities, with 51.2% of urban participants and 77.0% of rural participants reporting monthly incomes ≤ 10,000 Thai Baht.

The comprehensive statistical summaries for all measurement items across urban and rural subsamples, including means, standard deviations, skewness, kurtosis, and reliability coefficients, are provided in Appendix 2.1. Mean scores across all service quality dimensions ranged from 5.941 to 6.422 for urban participants and 5.953 to 6.283 for rural participants, indicating generally positive expectations toward sustainable public transport services. Standard deviation values ranged from 0.742 to 1.068 for urban areas and 0.799 to 1.035 for rural areas, suggesting moderate variability in responses within acceptable ranges for subsequent analyses. Skewness values were predominantly negative across both groups, ranging from -0.279 to -2.435 for urban participants and -0.336 to -1.151 for rural participants, indicating slight negative skew but within acceptable limits for structural equation modeling (±2.0). Kurtosis values varied more substantially, with some items exceeding recommended thresholds, particularly in the urban subsample, necessitating careful attention during model estimation procedures. All constructs demonstrated excellent internal consistency reliability, with Cronbach's alpha coefficients ranging from 0.804 to 0.915 across both urban and rural groups, substantially exceeding the recommended threshold of 0.70 and providing strong evidence for measurement reliability.

2.5.2 Confirmatory factor analysis results

2.5.2.1 Model fit assessment

The confirmatory factor analysis evaluated each measurement model's adequacy through comprehensive goodness-of-fit assessment across both geographical contexts. For the urban subsample (n=631), the measurement model demonstrated acceptable fit indices: χ^2 = 1227.299, df = 419, χ^2/df = 2.929, CFI = 0.959, TLI = 0.935, SRMR = 0.037, RMSEA = 0.055 (90% CI: 0.052-0.059). The rural subsample (n=558) exhibited superior fit statistics: χ^2 = 698.289, df = 437, χ^2/df = 1.598, CFI = 0.983, TLI = 0.974, SRMR = 0.026, RMSEA = 0.033 (90% CI: 0.028-0.037). Both models satisfied established criteria for good model fit, with CFI and TLI values exceeding 0.95 for rural areas and approaching this standard for urban areas. The χ^2/df ratios remained within acceptable ranges (<3.0 for rural, <5.0 for urban), while SRMR and RMSEA values demonstrated good absolute fit across both contexts. The superior fit statistics for rural participants suggest more consistent response patterns and potentially greater conceptual clarity regarding sustainable public transport service expectations within this demographic.

2.5.2.2 Convergent validity assessment

Examination of convergent validity through factor loadings, Average Variance Extracted (AVE), and Composite Reliability (CR) revealed mixed but generally acceptable results across the eleven service quality dimensions. As presented in Appendix 2.2, standardized factor loadings ranged from 0.581 to 0.890 for urban participants and 0.688 to 0.858 for rural participants, with most items exceeding the recommended threshold of 0.70. Average Variance Extracted values varied considerably across constructs and geographical contexts. For urban participants, AVE ranged from 0.338 (Information) to 0.792 (Convenience), with several constructs falling below the recommended threshold of 0.50, particularly Information (0.338) and Post-Pandemic Prevention (0.362). Rural participants demonstrated superior convergent validity, with AVE values ranging from 0.367 (Post-Pandemic Prevention) to 0.736 (Convenience), indicating more consistent measurement quality. Composite Reliability statistics exceeded the recommended threshold of 0.70 for all constructs across both groups, ranging from 0.806 to 0.940 for urban areas and 0.790 to 0.941 for rural areas, providing strong evidence for internal consistency reliability.

2.5.2.3 Internal consistency assessment

Internal consistency reliability demonstrated excellent performance across all service quality dimensions, with Cronbach's alpha coefficients substantially exceeding recommended standards. Reliability coefficients ranged from 0.804 (Older's Facilities) to 0.915 (Reliability) across both urban and rural contexts, providing strong evidence for the measurement instrument's internal consistency. Traditional service quality dimensions such as Safety and Security (α = 0.914), Staff (α = 0.912), and Reliability (α = 0.915) demonstrated the highest reliability, as presented in Appendix 2.1, while extended dimensions specific to elderly populations showed slightly lower but still excellent reliability coefficients. This pattern suggests that while the novel constructs (Older's Facilities and Post-Pandemic Prevention) are psychometrically sound, they represent well-defined conceptual domains that contribute meaningfully to the overall service quality framework.

2.5.2.4 Measurement invariance testing

The measurement invariance testing sequence examined whether the service quality measurement model operated equivalently across urban and rural elderly populations through systematic model comparison procedures. Table 2.3 presents comprehensive results for the invariance testing sequence. The configural invariance model (Model 3) established that the same eleven-factor structure was appropriate for both groups while allowing all parameters to be freely estimated across contexts. This simultaneous model demonstrated good fit: χ^2 = 1841.160, df = 812, χ^2/df = 2.267, CFI = 0.971, TLI = 0.952, SRMR = 0.032, RMSEA = 0.046 (90% CI: 0.043-0.049), providing strong evidence that the theoretical structure of sustainable public transport service quality expectations was consistent across urban and rural elderly populations.

The metric invariance model (Model 4) imposed equality constraints on factor loadings, intercepts, and structural paths across groups, testing whether measurement parameters operated equivalently between urban and rural contexts. This more restrictive model yielded slightly reduced but still acceptable fit: χ^2 = 1993.923, df = 901, χ^2/df = 2.213, CFI = 0.969, TLI = 0.954, SRMR = 0.039, RMSEA = 0.045 (90% CI: 0.043-0.048). The chi-square difference test indicated a significant change between models ($\Delta\chi^2$ = 152.763, Δdf = 89, $p < 0.001$), suggesting some differences in measurement parameters between groups. However, the change in practical fit indices was minimal, with ΔCFI = 0.002 well below the recommended threshold of 0.01, indicating that measurement invariance was tenable despite the significant chi-square difference.

Table 2.3 Model fit indices for invariance test

Description	χ^2	*df*	χ^2/*df*	CFI	TLI	SRMR	RMSEA (90% CI)	$\Delta\chi 2$	Δ*df*	*p*
Individual groups										
Model 1: Urban	1227.299	419	2.929	0.959	0.935	0.037	0.055 (0.052-0.059)			
Model 2: Rural	698.289	437	1.598	0.983	0.974	0.026	0.033 (0.028-0.037)			
Measurement of invariance										
Model 3: Simultaneous model	1841.160	812	2.267	0.971	0.952	0.032	0.046 (0.043-0.049)			
Model 4: Factor loading, intercepts, structural paths held equal across groups	1993.923	901	2.213	0.969	0.954	0.039	0.045 (0.043-0.048)	152.76	89	< 0.001

2.5.3 Second-order confirmatory factor analysis

The second-order confirmatory factor analysis examined the hierarchical structure of service quality expectations through separate analysis of urban (Model 1) and rural (Model 2) elderly populations. The measurement model demonstrated substantial explanatory power at both analytical levels, with first-order dimensions accounting for 69.26% (urban) and 68.08% (rural) of variance in observed items, while the second-order construct explained 59.37% (urban) and 57.00% (rural) of variance in first-order factors. These small differences (1.18% and 2.37%) across levels support the measurement invariance findings and confirm the model's consistent performance across geographical contexts.

For the urban subsample, the analysis demonstrated acceptable fit with second-order factor loadings ranging from 0.581 to 0.890, as illustrated in Figure 2.2. The strongest contributors to overall service quality expectations among urban elderly were Convenience (λ = 0.890), Staff (λ = 0.871), and Reliability (λ = 0.871), while Information (λ = 0.581) and Post-Pandemic Prevention (λ = 0.602) showed weaker associations with the overarching construct. The explained variance (R^2) values for second-order relationships varied considerably, with Convenience demonstrating the highest explained variance (R^2 = 0.792), followed by Staff and Reliability (R^2 = 0.759 each).

The rural subsample exhibited superior model fit with second-order factor loadings ranging from 0.606 to 0.858, as presented in Figure 2.3. Key contributors to overall service quality expectations among rural elderly included Convenience (λ = 0.858), Staff (λ = 0.850), and Safety and Security (λ = 0.811), while Post-Pandemic Prevention (λ = 0.606) and Vehicle (λ = 0.688) demonstrated relatively weaker associations. The pattern of explained variance was more balanced across dimensions in rural contexts, with the highest values observed for Convenience (R^2 = 0.736), Staff (R^2 = 0.722), and Reliability (R^2 = 0.677). Both models achieved acceptable second-order factor fit, with the overall Expected Public Transport Service Quality construct demonstrating adequate explanatory power across all first-order dimensions.

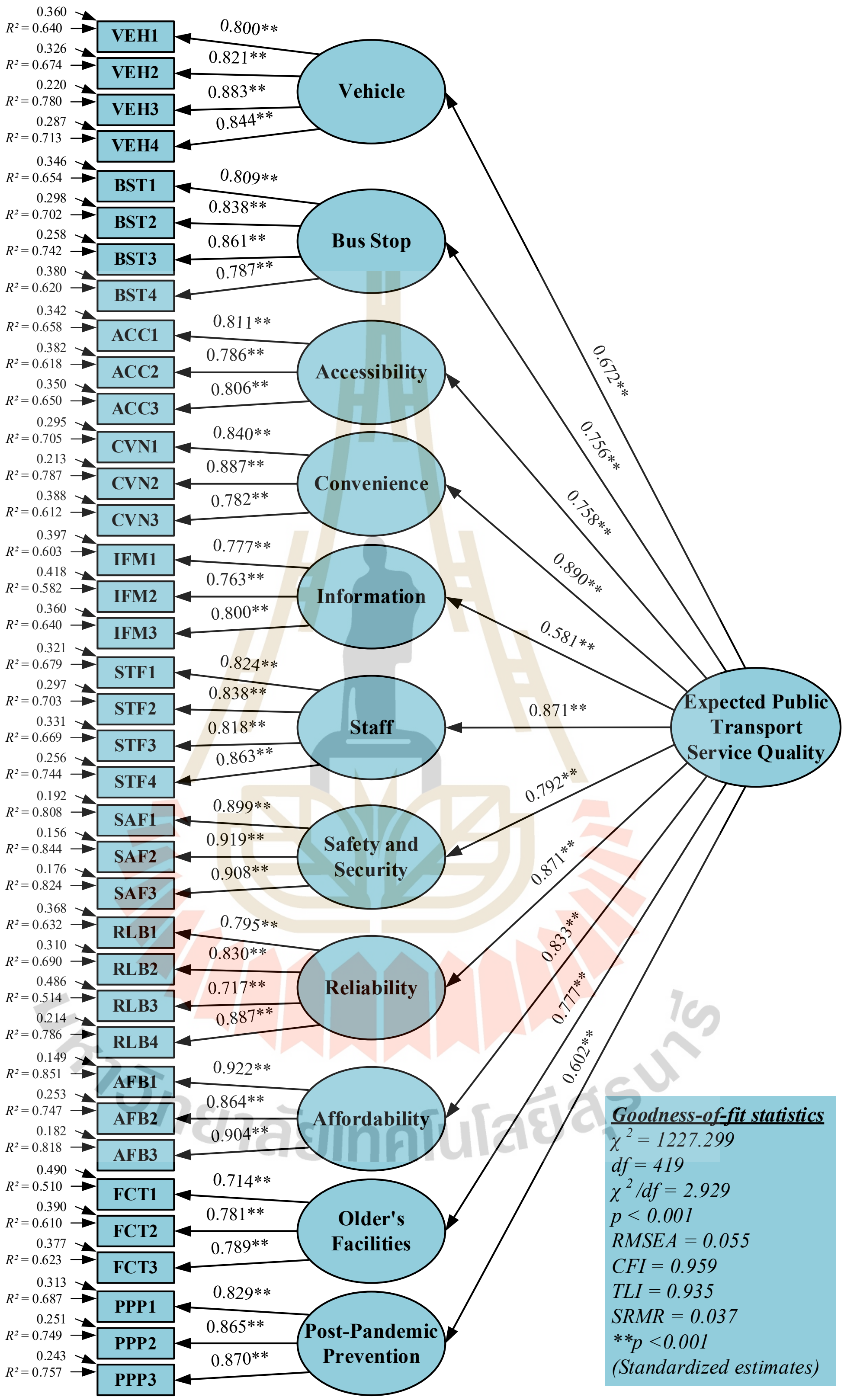

Figure 2.2 Second-order confirmatory factor analysis of the urban older adult group

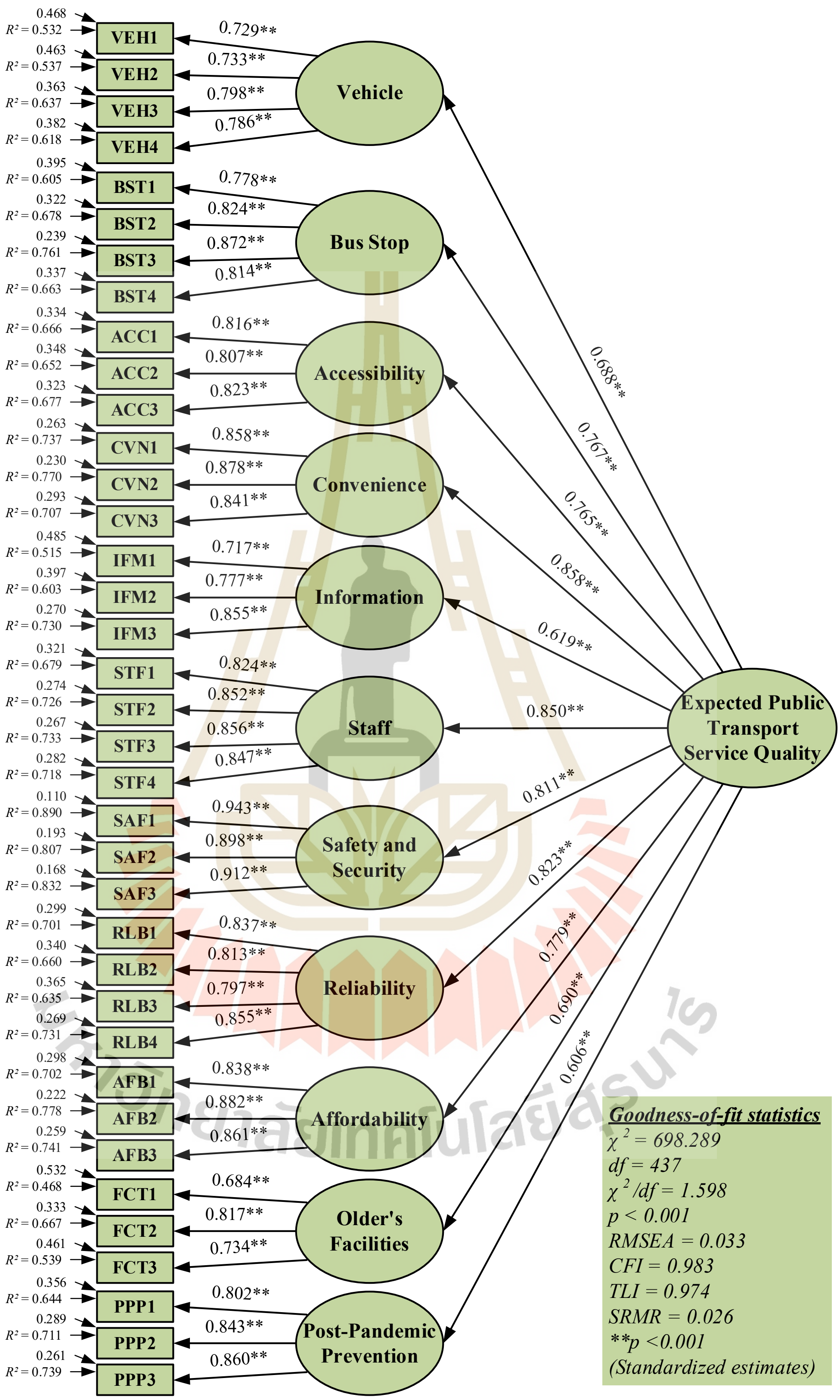

Figure 2.3 Second-order confirmatory factor analysis of the rural older adult group

2.6 Discussion

2.6.1 Measurement model performance and sustainability framework integration

The successful establishment of measurement invariance across urban and rural contexts validates the universality of sustainable public transport service quality expectations among elderly populations while also revealing context-specific adaptations that inform future transport planning. The configural invariance results demonstrate that the eleven-factor structure operates consistently across geographical contexts, indicating that fundamental sustainability principles, including environmental responsibility, social inclusion, and economic viability, transcend urban-rural boundaries in elderly populations' expectations (Ministry of Transport, 2020; United Nations, 2021).

The superior model fit in rural contexts compared to urban areas suggests that limited current service options may actually promote clearer expectations for future sustainable transport systems. This "expectation coherence through constraint" provides valuable insights for developing sustainable transport solutions that build upon existing clarity rather than adding complexity (Das & Pandit, 2015; Ponrahono et al., 2016).

2.6.2 Sustainable service quality dimensions and future-oriented expectations

2.6.2.1 Traditional dimensions in sustainability context

The consistent prioritization of Convenience, Staff quality, and Reliability across contexts indicates that sustainable public transport must integrate operational excellence with environmental responsibility (De Oña & De Oña, 2015; Zhang et al., 2019). These findings suggest that future sustainable transport systems should emphasize seamless multimodal integration, predictable service delivery, and professionally trained staff capable of supporting diverse passenger needs (Fu et al., 2018; Nguyen-Phuoc et al., 2021).

The elevated importance of Safety and Security in rural contexts highlights the need for sustainable transport solutions that address infrastructure vulnerabilities while incorporating renewable energy sources and environmentally responsible security technologies (Mandhani et al., 2023; van Lierop & El-Geneidy, 2016).

2.6.2.2 Extended dimensions for sustainable futures

The validation of Older's Facilities as a distinct dimension supports the integration of universal design principles into sustainable transport planning (Broome et al., 2013; Shrestha et al., 2017). Future sustainable systems must incorporate age-friendly technologies including smart information systems, renewable energy-powered accessibility features, and environmentally sustainable materials in specialized infrastructure (Wong et al., 2017; Yuan et al., 2019).

The Post-Pandemic Prevention dimension demonstrates that health protection measures have become permanent expectations, requiring sustainable transport systems to integrate environmental health considerations with public health protection through innovative air filtration systems, antimicrobial materials, and energy-efficient health monitoring technologies (Chuenyindee et al., 2022; Li et al., 2022; Tirachini & Cats, 2020).

2.6.3 Urban-rural sustainability adaptation strategies

The measurement model reveals that while elderly populations share fundamental sustainability expectations, implementation strategies must acknowledge contextual differences (Champahom et al., 2025; Wisutwattanasak et al., 2023). Urban elderly prioritize system integration and operational efficiency, suggesting future sustainable transport should emphasize electric bus rapid transit, integrated renewable energy systems, and smart mobility platforms that reduce environmental impact while enhancing convenience (Li et al., 2020; Too & Earl, 2010).

Rural elderly emphasize safety and staff quality, indicating that sustainable rural transport solutions should focus on demand-responsive electric vehicles, community-based sustainable transport programs, and locally-sourced renewable energy infrastructure that maintains human-centered service delivery while achieving environmental goals (Cui et al., 2023; Mahmoud & Hine, 2016). This aligns with previous research demonstrating significant disparities between urban and rural transport service quality and the need for context-specific solutions (Ponrahono et al., 2016; Sum et al., 2019).

2.7 Conclusions and implications

2.7.1 Conclusions summary

This research establishes the first validated measurement framework for sustainable public transport service quality expectations among elderly populations across urban-rural contexts in developing countries, providing significant empirical evidence for advancing sustainable transport development in aging societies. The successful establishment of configural and metric invariance across urban and rural elderly populations confirms that the eleven-factor framework operates equivalently across geographical contexts, validating that elderly passengers maintain consistent cognitive frameworks for evaluating future sustainable transport services. Universal priorities for Convenience, Staff quality, and Reliability indicate that sustainable transport must prioritize operational excellence alongside environmental responsibility, while context-specific findings show elevated Safety and Security importance in rural areas, providing guidance for targeted investment strategies (De Oña & De Oña, 2015; Mandhani et al., 2023). The validation of Older's Facilities and Post-Pandemic Prevention establishes empirical support for incorporating age-inclusive design and health protection measures as permanent components of sustainable transport planning, extending traditional SERVQUAL frameworks (Shrestha et al., 2017; Tirachini & Cats, 2020). These measurement invariance results justify unified national standards for elderly-friendly sustainable transport while accommodating regional variations and advance service quality theory by demonstrating that elderly populations possess sophisticated, multidimensional expectations for future sustainable transport that require both specific attribute evaluation and holistic service conceptualization. These findings establish a comprehensive foundation for developing and evaluating sustainable public transport systems that effectively serve aging populations while achieving sustainability objectives, contributing essential knowledge for Thailand's demographic transition and global sustainable transport development.

2.7.2 Policy implications for sustainable transport development

2.7.2.1 National sustainable transport strategy

The measurement invariance findings justify developing unified national standards for sustainable elderly-friendly public transport that integrate environmental sustainability with social accessibility. National policies should mandate:

1) Integrated Sustainable Systems: Electric bus networks with renewable energy integration, emphasizing Convenience and Reliability priorities identified across both contexts (Fu et al., 2018; Zhang et al., 2019).

2) Age-Inclusive Sustainable Design: Universal design principles incorporating energy-efficient accessibility features, smart information systems powered by renewable sources, and sustainable materials in elderly-specific infrastructure (Shrestha et al., 2017; Wong et al., 2018).

3) Staff Development for Sustainability: Training programs that combine elderly passenger service skills with sustainability awareness and green technology operation (Nguyen-Phuoc et al., 2021; Ratanavaraha & Jomnonkwao, 2014).

2.7.2.2 Context-specific sustainable implementation

Regional implementation strategies should reflect the differential priority patterns revealed through the measurement model analysis, with urban transport emphasizing seamless integration with existing systems and rural transport prioritizing safety infrastructure improvements and community-based transport solutions.

1) Urban Sustainable Transport: Prioritize electric bus rapid transit systems, integrated renewable energy infrastructure, smart mobility platforms, and multimodal sustainable transport hubs that reduce environmental impact while enhancing operational convenience and reliability (Jomnonkwao et al., 2020; Li et al., 2020).

2) Rural Sustainable Transport: Develop demand-responsive electric vehicle services, community-based sustainable transport cooperatives, locally-sourced renewable energy charging infrastructure, and hybrid conventional-sustainable service models that maintain human-centered service delivery while progressing toward environmental goals (Champahom et al., 2025; Lin & Cui, 2021).

2.7.3 Sustainable transport innovation directions

The research identifies specific innovation priorities for sustainable public transport development that build upon the validated measurement model:

1) Technology Integration: Age-friendly smart systems powered by renewable energy that enhance convenience while reducing environmental impact (Zhou et al., 2019) (Wu et al., 2016).

2) Health-Environment Integration: Sustainable health protection technologies including energy-efficient air filtration, renewable-powered antimicrobial systems, and environmentally responsible cleaning protocols (Ding et al., 2023; Gkiotsalitis & Cats, 2021).

3) Community-Centered Sustainability: Sustainable transport solutions that maintain high-quality staff interaction while incorporating environmental responsibility and local community involvement (Joewono et al., 2016; Sinha et al., 2020).

2.7.4 Future research for sustainable transport

Future research should extend this measurement framework through several critical directions that build upon the validated eleven-factor structure. Longitudinal studies examining how sustainable transport innovations affect elderly mobility, satisfaction, and environmental outcomes would track the translation of expectations into actual service experiences and assess measurement model stability as sustainable systems are implemented. Investigation of elderly passengers' acceptance and adaptation to emerging technologies such as autonomous vehicles, smart payment systems, and real-time information platforms across urban-rural contexts would reveal how technological advancement integrates with established service quality dimensions. Cross-cultural validation studies expanding the framework to diverse international contexts would strengthen theoretical foundations and enhance global applicability for sustainable transport development. Research examining the relationship between service quality satisfaction and environmental sustainability outcomes would provide comprehensive understanding of the sustainability-satisfaction nexus, particularly whether higher service quality perceptions correlate with increased ridership and subsequent environmental benefits. These research directions will provide crucial evidence for policy makers regarding the practical value of investing in comprehensive sustainable transport systems that effectively serve aging populations while achieving environmental sustainability goals.

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Appendix 2.1 Statistical summary

Item	Measures	Urban (n= 631)				Rural (n = 558)			
		Mean	SD	SK	KU	Mean	SD	SK	KU
	Vehicle (Cronbach's α = 0.886)								
VEH1	Buses interiors have adequate lighting	6.357	0.842	-2.095	8.229	6.283	0.799	-0.702	-0.633
VEH2	Buses interiors are free from disturbing noise and vibration	6.317	0.861	-1.993	6.923	6.240	0.849	-1.027	0.975
VEH3	Buses have adequate seating space and comfort	6.422	0.837	-2.435	10.137	6.278	0.885	-1.151	1.064
VEH4	Overall, Bus is in good condition and feels safe	6.296	0.890	-1.821	5.936	6.238	0.892	-0.912	-0.011
	Bus Stop (Cronbach's α = 0.900)								
BST1	Bus stops are clean and usable	6.128	1.016	-1.115	1.009	6.129	0.925	-0.805	-0.229
BST2	Bus stops have weather protection	6.051	0.970	-0.877	0.710	6.052	0.934	-0.675	-0.373
BST3	Bus stops have adequate lighting	6.127	0.997	-1.047	1.067	6.090	0.951	-0.758	-0.108
BST4	Bus stops have adequate seating and waiting space	6.117	0.869	-1.089	2.241	6.066	0.907	-0.681	-0.264
	Accessibility (Cronbach's α = 0.866)								
ACC1	Appropriate distance from home to bus stop	6.090	0.959	-1.231	2.750	5.971	0.991	-0.675	-0.088
ACC2	Bus stop location is appropriate and accessible	6.124	0.978	-0.975	0.624	5.984	0.998	-0.664	-0.203
ACC3	Bus routes comprehensively cover various areas	5.941	1.065	-0.800	0.042	5.953	1.035	-0.657	-0.438
	Convenience (Cronbach's α = 0.894)								
CVN1	Convenient connections with other transport modes	6.117	0.881	-1.208	3.311	6.023	0.929	-0.572	-0.591
CVN2	Convenient boarding and alighting	6.206	0.872	-1.363	3.197	6.066	0.978	-0.677	-0.630
CVN3	Adequate and convenient luggage storage	6.165	0.932	-1.278	2.733	5.975	0.981	-0.580	-0.450
	Information (Cronbach's α = 0.850)								
IFM1	Adequate travel information at bus stops	6.349	0.742	-1.595	6.041	6.240	0.830	-0.908	0.264
IFM2	Adequate travel information on buses	6.342	0.797	-1.542	4.533	6.152	0.883	-0.805	0.276
IFM3	Advance notification of schedule changes	6.320	0.880	-1.668	4.683	6.159	0.904	-0.832	0.198

Note: SD denote standard deviation, SK denote skewness, KU denote kurtosis.

Appendix 2.1 Statistical summary (Continued)

Item	Measures	Urban (n= 631)				Rural (n = 558)			
		Mean	SD	SK	KU	Mean	SD	SK	KU
	Staff (Cronbach's α = 0.912)								
STF1	Driver/staff are ready for work (well-rested, sober)	6.315	0.884	-1.601	4.113	6.165	0.961	-0.894	-0.126
STF2	Driver/staff are dedicated and willing to serve	6.314	0.894	-1.847	5.753	6.158	0.970	-0.900	-0.132
STF3	Driver/staff provide polite and friendly service	6.322	0.878	-1.776	5.759	6.186	0.942	-0.922	-0.012
STF4	Driver/staff have good attitudes toward elderly	6.358	0.848	-1.916	6.883	6.149	0.972	-0.842	-0.327
	Safety and security (Cronbach's α = 0.914)								
SAF1	Safe bus stop usage (no obstacles, non-slip surfaces)	6.124	0.886	-1.124	2.745	5.984	0.935	-0.550	-0.588
SAF2	Personal and property safety during travel	6.220	0.847	-1.441	4.280	6.054	0.970	-0.723	-0.420
SAF3	Personal and property safety at bus stops	6.208	0.847	-1.290	3.123	6.034	0.961	-0.750	-0.084
	Reliability (Cronbach's α = 0.915)								
RLB1	Service follows schedule	5.987	0.946	-0.843	1.596	6.034	0.925	-0.560	-0.626
RLB2	Punctual arrivals and departures	6.097	0.942	-1.211	2.991	6.063	0.960	-0.640	-0.641
RLB3	Buses follow designated routes and stops	6.002	0.975	-0.755	0.456	6.034	0.948	-0.576	-0.734
RLB4	Appropriate waiting times	6.078	0.904	-1.265	3.683	6.039	0.939	-0.601	-0.656
	Affordability (Cronbach's α = 0.906)								
AFB1	Good value for money	6.238	0.851	-1.126	1.328	6.154	0.921	-0.836	-0.250
AFB2	Discounted rates for weekly/monthly/annual passes	6.168	0.886	-1.105	0.943	6.084	0.965	-0.746	-0.453
AFB3	Reasonable fare increases with better service	6.171	0.913	-0.997	0.380	6.079	1.003	-0.769	-0.488
	Older's facilities (Cronbach's α = 0.804)								
FCT1	Clear visual and audio information on buses	6.177	0.869	-1.253	2.385	6.145	0.838	-0.848	0.508
FCT2	Handrails and stair rails on buses	6.225	0.841	-1.327	3.915	6.145	0.870	-0.894	1.035
FCT3	Ramps/lifts for wheelchair users on buses	6.217	0.947	-1.581	3.966	6.140	0.896	-0.894	0.614

Note: SD denote standard deviation, SK denote skewness, KU denote kurtosis.

Appendix 2.1 Statistical summary (Continued)

Item	Measures	Urban (n= 631)				Rural (n = 558)			
		Mean	SD	SK	KU	Mean	SD	SK	KU
	Post-Pandemic Prevention (Cronbach's α = 0.891)								
PPP1	Screening measures during outbreaks (registration, vaccination checks, temperature checks)	6.166	0.982	-1.287	2.116	6.100	0.933	-0.707	-0.452
PPP2	Prevention measures during outbreaks (distancing, masks, barriers)	6.211	0.933	-1.312	2.503	6.093	0.939	-0.931	0.778
PPP3	Control measures during outbreaks (hand washing, cleaning procedures)	6.233	1.068	-1.604	2.399	6.109	0.998	-0.972	0.413

Note: SD denote standard deviation, SK denote skewness, KU denote kurtosis.

Appendix 2.2 Parameters estimation of measurement model

Constructs and indicators	Urban (n = 631)			Rural (n = 558)		
	λ	t-value	R^2	λ	t-value	R^2
Vehicle	(AVE = 0.702, CR = 0.904)			(AVE = 0.581, CR = 0.847)		
VEH1	0.800	36.354**	0.640	0.729	25.540**	0.532
VEH2	0.821	39.604**	0.674	0.733	25.835**	0.537
VEH3	0.883	33.277**	0.780	0.798	24.747**	0.637
VEH4	0.844	43.468**	0.713	0.786	31.900**	0.618
Bus Stop	(AVE = 0.679, CR = 0.894)			(AVE = 0.677, CR = 0.893)		
BST1	0.809	47.166**	0.654	0.778	38.650**	0.605
BST2	0.838	48.834**	0.702	0.824	43.711**	0.678
BST3	0.861	56.817**	0.742	0.872	58.418**	0.761
BST4	0.787	43.055**	0.620	0.814	46.058**	0.663
Accessibility	(AVE = 0.642, CR = 0.843)			(AVE = 0.665, CR = 0.856)		
ACC1	0.811	40.699**	0.658	0.816	39.157**	0.666
ACC2	0.786	37.262**	0.618	0.807	37.622**	0.652
ACC3	0.806	40.889**	0.650	0.823	42.353**	0.677
Convenience	(AVE = 0.701, CR = 0.875)			(AVE = 0.738, CR = 0.894)		
CVN1	0.840	38.067**	0.705	0.858	36.336**	0.737
CVN2	0.887	53.238**	0.787	0.878	51.539**	0.770
CVN3	0.782	39.454**	0.612	0.841	45.781**	0.707
Information	(AVE = 0.609, CR = 0.823)			(AVE = 0.616, CR = 0.827)		
IFM1	0.777	31.008**	0.603	0.717	24.973**	0.515
IFM2	0.763	29.841**	0.582	0.777	29.337**	0.603
IFM3	0.800	34.718**	0.640	0.855	35.468**	0.730
Staff	(AVE = 0.699, CR = 0.903)			(AVE = 0.714, CR = 0.909)		
STF1	0.824	44.751**	0.679	0.824	42.809**	0.679
STF2	0.838	55.026**	0.703	0.852	53.818**	0.726
STF3	0.818	39.159**	0.669	0.856	42.112**	0.733
STF4	0.863	56.017**	0.744	0.847	47.799**	0.718
Safety and security	(AVE = 0.826, CR = 0.934)			(AVE = 0.842, CR = 0.941)		
SAF1	0.899	35.906**	0.808	0.943	39.776**	0.890
SAF2	0.919	77.047**	0.844	0.898	64.833**	0.807
SAF3	0.908	75.235**	0.824	0.912	68.254**	0.832
Reliability	(AVE = 0.655, CR = 0.883)			(AVE = 0.682, CR = 0.896)		
RLB1	0.795	36.297**	0.632	0.837	31.522**	0.701
RLB2	0.830	50.734**	0.690	0.813	39.591**	0.660
RLB3	0.717	28.157**	0.514	0.797	30.491**	0.635
RLB4	0.887	56.809**	0.786	0.855	43.292**	0.731
Affordability	(AVE = 0.805, CR = 0.925)			(AVE = 0.740, CR = 0.895)		
AFB1	0.922	91.307**	0.851	0.838	48.899**	0.702
AFB2	0.864	60.202**	0.747	0.882	49.522**	0.778
AFB3	0.904	81.283**	0.818	0.861	47.901**	0.741

Note: ** significant at $p < 0.001$; * significant at $p < 0.05$, λ denote standardized loading.

Appendix 2.2 Parameters estimation of measurement model (Continued)

Constructs and indicators	Urban (n = 631)			Rural (n = 558)		
	λ	t-value	R^2	λ	t-value	R^2
Older's facilities	(AVE = 0.581, CR = 0.806)			(AVE = 0.558, CR = 0.790)		
FCT1	0.714	26.847**	FCT1	0.714	26.847**	FCT1
FCT2	0.781	26.836**	FCT2	0.781	26.836**	FCT2
FCT3	0.789	32.400**	FCT3	0.789	32.400**	FCT3
Post-pandemic prevention	(AVE = 0.731, CR = 0.891)			(AVE = 0.698, CR = 0.874)		
PPP1	0.829	40.233**	PPP1	0.829	40.233**	PPP1
PPP2	0.865	48.359**	PPP2	0.865	48.359**	PPP2
PPP3	0.870	47.722**	PPP3	0.870	47.722**	PPP3
Expected public transport service quality	(AVE = 0.594, CR = 0.940)			(AVE = 0.570, CR = 0.935)		
Vehicle	0.672	25.149**	0.452	0.688	22.340**	0.473
Bus stop	0.756	33.646**	0.571	0.767	32.840**	0.588
Accessibility	0.758	31.587**	0.574	0.765	30.798**	0.585
Convenience	0.890	42.592**	0.792	0.858	39.485**	0.736
Information	0.581	17.217**	0.338	0.619	17.613**	0.383
Staff	0.871	45.316**	0.759	0.850	39.209**	0.722
Safety and security	0.792	40.025**	0.627	0.811	38.902**	0.657
Reliability	0.871	43.140**	0.759	0.823	34.675**	0.677
Affordability	0.833	45.340**	0.693	0.779	31.694**	0.606
Older's facilities	0.777	26.693**	0.604	0.690	21.421**	0.476
Post-pandemic prevention	0.602	19.322**	0.362	0.606	17.777**	0.367

Note: ** significant at $p < 0.001$; * significant at $p < 0.05$, λ denote standardized loading.

CHAPTER III

DETERMINANTS OF ELDERLY PASSENGER LOYALTY IN THAILAND'S PUBLIC TRANSPORTATION: A POST-PANDEMIC PERSPECTIVE

3.1 Abstract

This study investigates factors influencing public transportation loyalty among Thailand's elderly population from a post-pandemic perspective using Structural Equation Modeling. Data were collected from 2,000 elderly participants across Thailand's five regions. The model examined relationships between expected service quality, perceived service quality, perceived value, passenger satisfaction, passenger trust, passenger commitment, alternative attractiveness, switching costs, and passenger loyalty. Results confirmed 13 of 14 hypothesized relationships, revealing that passenger trust (β = 0.392), passenger commitment (β = 0.277), and perceived value (β = 0.219) were the strongest direct predictors of loyalty, while perceived service quality demonstrated an exceptionally strong effect on trust (β = 0.807). Contrary to expectations, alternative attractiveness did not significantly affect loyalty. These findings emphasize the importance of specialized facilities for elderly passengers and post-pandemic prevention measures as critical components of service quality perceptions, highlighting the service quality-trust-loyalty pathway that can guide transportation providers in developing effective strategies to enhance elderly mobility and social participation in Thailand's rapidly aging society.

3.2 Introduction

3.2.1 Research background

Thailand has transitioned into an Aged Society, defined as a country in which more than 10% of the population is aged 60 or above (Department of Older Persons, 2022). The elderly population in Thailand is categorized into three distinct age groups: young-old (60–69 years), middle-old (70–79 years), and oldest-old (80 years and above). In 2022, approximately 12.47 million people in Thailand were aged 60 or over (18.86% of the population), exceeding the ASEAN average of 11.74% and ranking second after Singapore (22.96%) (United Nations, 2023). Moreover, Thailand's total population is projected to decrease from 66 million to 60 million over the next 20 years. Concurrently, the elderly population will grow significantly to 18.9 million by 2042, constituting 31.44% of the population and transforming Thailand into a 'Super-Aged Society' (Department of Older Persons, 2022).

This rapid demographic transition creates substantial challenges for mobility and transportation systems throughout the country. Notably, elderly individuals in Thailand predominantly favor private transportation over public alternatives: private cars account for 23.63% of transport use, motorcycles for 27.86%, while public transit systems represent only 9.70% of their transportation choices (Champahom et al., 2020). This trend is consistent with findings by Srichuae et al. (2016), who found that elderly people in Bangkok rely primarily on walking (26.3%), private vehicles (24.3%), public buses and vans (20.4%), taxis (14.7%), and urban rail (0.7%), demonstrating the persistently low intention and loyalty toward public transportation among Thailand's elderly population. Similar to many developing countries, the elderly in Thailand face significant barriers to accessing public transport services, which consequently negatively impacts their quality of life and social participation (Jahangir et al., 2024; Thaithatkul et al., 2022). Consequently, this low utilization of public transportation among the elderly presents important challenges in not only increasing their ridership but also, more critically, fostering loyalty among elderly users of public transportation systems.

According to the Transportation Research Board (1999), customer loyalty encompasses both attitudinal and behavioral elements. While primarily influenced by customer satisfaction, it also requires consumers to commit to ongoing investment in maintaining their relationship with transit service providers. Loyalty to public transportation is a multifaceted concept that plays a crucial role in retaining existing users and encouraging private vehicle users to switch to public transit alternatives (Imaz et al., 2015; Li et al., 2018). In this context, service quality emerges as a pivotal factor influencing passenger loyalty, as demonstrated in studies from Shanghai and other metropolitan areas, where high service quality correlates with increased passenger satisfaction and loyalty (de Oña & de Oña, 2023; Li et al., 2018). Furthermore, research in Xiamen, China, found that many passengers exhibit spurious loyalty, continuing to use public transit due to high switching costs rather than genuine satisfaction, thus highlighting the importance of improving service attributes like bus speed and convenience to enhance true loyalty (Sun & Duan, 2019).

The elderly population often faces unique mobility challenges, and consequently, public transport services must be tailored to meet their specific needs to ensure they remain active and socially engaged (Shrestha et al., 2017). Research have identified that the condition of stations and drivers' attitudes are critical to elderly satisfaction with public transport services (Wong et al., 2017). In the Thai context specifically, safety equipment and reliable service are highlighted as essential improvements needed to meet the expectations of elderly passengers (Chaisomboon et al., 2020). Similarly, in Harbin, elements such as site broadcasting, complaint handling, and punctuality are identified as key areas for enhancing elderly satisfaction (Lan et al., 2022). Paratransit services, which are vital for older adults, especially those with disabilities, often face challenges such as inefficiency and ableist interactions that need addressing to improve overall service quality (Fique et al., 2024).

The review of existing literature consistently demonstrates that passenger loyalty is closely tied to perceived service quality, satisfaction, and perceived value, all of which are essential for retaining current users and attracting new ones (Carvalho dos Reis Silveira et al., 2022; van Lierop et al., 2018). Specifically, research conducted on elderly residents in Harbin, China revealed that passenger loyalty stems directly from satisfaction levels, where perceived service quality exerts the strongest positive influence on satisfaction, followed by perceived value, while passenger expectations demonstrated the least significant impact (Yuan et al., 2019). In the context of Thailand, studies on various transportation modes have revealed consistent patterns in customer loyalty factors. For instance, research on both urban railways and educational tour buses indicates that satisfaction and perceived value significantly influence passenger loyalty (Jomnonkwao et al., 2015; Wonglakorn et al., 2021). Similarly, in the Thai airline industry, customer satisfaction, trust, perceived quality, and the airline's image significantly influence passenger loyalty. These elements are essential for developing effective marketing strategies and maintaining competitiveness, particularly in the face of recent pandemic challenges (Chanpariyavatevong et al., 2021; Chonsalasin et al., 2020).

The COVID-19 pandemic has fundamentally transformed travel behaviors and public transit operations worldwide. As Beck and Hensher (2020) observe, even as economic activities gradually resume normalcy, lingering activity habit changes and infection fears continue to exert negative impacts on public transport systems. This transformation has resulted in significant reductions in ridership across various transit systems (Hsieh, 2023; Hsieh & Hsia, 2022), creating substantial financial burdens for operators and prompting service quality reductions. Additionally, the pandemic has unveiled inequitable impacts on different user demographics, with socio-economically disadvantaged groups experiencing disproportionate effects (Ancheta et al., 2023; Liu & Lee, 2023).

In this post-pandemic context, the perspective on elderly passengers' transportation needs has fundamentally shifted. The pandemic has not only reduced ridership but also transformed service quality expectations, particularly among vulnerable elderly populations who faced heightened health risks. Research by Wisutwattanasak et al. (2023) emphasizes that there is now an increased focus on health and safety among potential passengers in Thailand, with safety and health considerations significantly influencing users' intentions to utilize public transport. Their study specifically found that Thailand's public transportation suffered significant consequences as the tourism and service sectors, which contribute to 52.4% of GDP, are severely affected. Furthermore, research on elderly travelers' expectations of high-speed railway services in Thailand by Champahom et al. (2025) reveals that post-pandemic considerations have become integral to service quality assessment, with elderly passengers showing heightened awareness of health safety protocols and infection prevention measures. Notably, their study identified facilitating conditions as one of the strongest determinants influencing elderly travelers' expectations, particularly for other-purpose travelers, emphasizing the critical importance of supportive infrastructure, staff assistance, and accessible information systems in the post-pandemic transportation environment. This post-pandemic perspective has introduced new dimensions of service evaluation where traditional factors like reliability and convenience must now be complemented by enhanced sanitation protocols, infection prevention measures, and health safety assurances that are particularly critical for elderly passengers' trust and loyalty formation.

Therefore, understanding the hierarchy of transit needs in this post-COVID-19 context is crucial for efficient transit service improvement. Allen, Muñoz and de Dios Ortúzar (2019) previously established a pre-pandemic hierarchy of transit needs, but the restructuring of these needs after the pandemic remains underexplored. Nevertheless, Dong et al. (2021) identified infection concern as a critical component of post-COVID-19 transit service satisfaction, significantly impacting overall safety perceptions. Furthermore, Aghabayk et al. (2021) found increased sensitivity to crowding among transit users, while several studies emphasized the importance of ventilation and physical distancing in public transport during the pandemic (Li et al., 2022; Luo et al., 2024). The findings from Champahom et al. (2025) further reinforce this evolving landscape, demonstrating that facilitating conditions, including supportive infrastructure, clear information systems, and staff assistance, have become crucial determinants of elderly passengers' service expectations in Thailand's transportation context. This evolving landscape thus necessitates a comprehensive examination of service quality dimensions, specifically identifying the determinants that support and enhance satisfaction and loyalty among elderly passengers in the post-pandemic era.

3.2.2 Research gap and objectives

This study aims to investigate the key factors influencing public transportation loyalty among Thailand's elderly population from a post-pandemic perspective using Structural Equation Modeling (SEM). Despite the extensive body of literature on transportation service quality and passenger loyalty (Carvalho dos Reis Silveira et al., 2022; van Lierop et al., 2018), several significant research gaps remain, particularly in understanding the complex interrelationships between service quality factors, satisfaction, and loyalty specifically for elderly passengers in the post-pandemic context (Esmailpour et al., 2022; Hsieh, 2023; Hsieh & Hsia, 2022). By developing and testing a comprehensive conceptual model that captures the multidimensional nature of loyalty formation among the elderly, this study addresses two critical research gaps.

First, although loyalty determinants have been extensively studied for general populations, research specifically examining elderly passengers remains limited, as shown in Table 3.1. A notable study by Yuan et al. (2019), who investigated elderly residents in Harbin, China, found that passenger loyalty stems directly from satisfaction levels, with perceived service quality exerting the strongest positive influence on satisfaction, followed by perceived value, while passenger expectations demonstrated the least significant impact. However, despite these valuable insights, comprehensive models examining how these factors collectively influence elderly loyalty in developing countries like Thailand are still lacking, particularly regarding the interrelationships between service quality expectations, trust, commitment, and other potential determinants of loyalty. This research aims to address this gap by developing and empirically validating a model that incorporates nine key constructs including expected service quality, perceived service quality, perceived value, passenger satisfaction, passenger trust, passenger commitment, alternative attractiveness, switching costs, and passenger loyalty.

Second, traditional service quality frameworks that impact satisfaction and loyalty typically focus on standard dimensions like reliability, frequency, and convenience (Allen, Muñoz, & de Dios Ortúzar, 2019). However, two emerging dimensions require specific attention in the post-pandemic context. Elderly passengers need specialized facilities and support services that are rarely incorporated into standard service quality assessments (Shrestha et al., 2017), with safety equipment and reliable service being essential for Thai elderly passengers (Chaisomboon et al., 2020). Additionally, the COVID-19 pandemic has fundamentally transformed travel behaviors and public transit operations, with post-pandemic concerns including infection fears, increased sensitivity to crowding, and importance of ventilation emerging as critical factors (Aghabayk et al., 2021; Dong et al., 2021; Li et al., 2022). Research by Wisutwattanasak et al. (2023) demonstrates that safety and health considerations now significantly influence users' intentions to utilize public transport in Thailand, while Champahom et al. (2025) found that facilitating conditions have become crucial determinants of elderly passengers' service expectations in the post-pandemic transportation environment. However, few studies have systematically integrated these pandemic-related considerations as formal dimensions of service quality, particularly for vulnerable elderly populations (Chuenyindee et al., 2022; Gkiotsalitis & Cats, 2021; Hsieh, 2023). This research addresses these gaps by explicitly incorporating "Facilities and support for the elderly" and "Post-pandemic prevention" as distinct service quality dimensions in both expected and perceived service quality assessments, providing valuable insights for developing elderly-friendly public transportation systems in Thailand's post-pandemic, rapidly aging society.

3.3 Literature review

Multiple interrelated factors influence elderly passengers' loyalty to public transportation systems, as extensively documented in transportation and service marketing literature. Understanding these relationships is crucial for developing effective strategies to enhance elderly ridership and loyalty, particularly regarding specialized service quality dimensions that address elderly-specific mobility needs and post-pandemic safety concerns. This section reviews the theoretical foundations and empirical evidence regarding the key determinants of public transportation loyalty among elderly users. The literature review is organized into eight key constructs that form the basis of the proposed conceptual model.

3.3.1 Loyalty-satisfaction theory

The concept of loyalty was initially defined by Jacoby (1971) as a biased behavioral response expressed over time with respect to one or more alternatives and is a function of psychological processes. In the public transport realm, customer loyalty refers to “a deeply held commitment to repurchase or re-patronize a preferred product or service in the future" (Oliver, 1999). It is typically measured through behavioral intentions such as willingness to continue using the service and willingness to recommend it to others (Reichheld, 2003; van Lierop & El-Geneidy, 2016). Some researchers also include overall satisfaction as part of the loyalty construct (Allen, 2004; Transportation Research Board, 1999), while others argue that satisfaction influences loyalty but should not be included in its definition (Bloemer et al., 1998; Zhao et al., 2014). The relationship between loyalty and satisfaction has been extensively studied across various service industries, including public transportation, which has guided much research in this field, posits that satisfaction is a key antecedent to loyalty (Fornell et al., 1996; Lai & Chen, 2011; Webb, 2010).

The loyalty-satisfaction theory has been widely applied in public transportation research, where numerous studies have confirmed the significant positive relationship between passenger satisfaction and loyalty (Chou & Kim, 2009; van Lierop & El-Geneidy, 2016), with satisfaction often mediating the impact of service quality on loyalty (Fu et al., 2018; Jen et al., 2011). However, while satisfaction is necessary for developing loyalty, it is not always sufficient, as other factors such as service quality, perceived value, trust, commitment, alternatives attractiveness and switching costs also play crucial roles in the loyalty formation process (Carvalho dos Reis Silveira et al., 2022).

3.3.2 Service quality

Service quality has been conceptualized as a cognitive judgment based on the comparison between customer expectations and perceived service performance (Gronroos, 1988). In public transportation, this concept directly influences ridership and system viability. Parasuraman et al. (1988) expanded this framework by proposing five assessment dimensions: Tangibles, Reliability, Responsiveness, Assurance, and Empathy, which have been widely applied to transportation services.

Recent empirical studies have expanded understanding of how service quality perceptions form in public transportation contexts. Jomnonkwao et al. (2020) examined this relationship in Thai railway services, finding that passengers' pre-service expectations significantly affected their perception of service delivered. When expectation-perception gaps were minimized, overall satisfaction increased. Similarly, Choi et al. (2025) analyzed these gaps in Korean metropolitan areas, confirming that expected service quality serves as a reference point against which passengers evaluate their actual experience. Even in areas with objectively better service, higher expectations could lead to larger perception gaps and reduced satisfaction. Deb et al. (2022) further reinforced this relationship by identifying that passengers' dissatisfaction indexes, calculated as the difference between expected and perceived service quality, strongly predicted overall satisfaction with bus services. These studies demonstrate that both expected and perceived service quality are essential for understanding satisfaction and fostering loyalty among elderly passengers.

The measurement of service quality in public transportation for elderly users represents the unique focus of this research. Based on comprehensive studies by Chaisomboon et al. (2020) and Lan et al. (2022), several key service quality indicators have been identified as crucial for elderly users. Additionally, Bakar et al. (2022) categorized service quality into 13 distinct dimensions including service frequency, on-time performance, passenger load, comfort, and safety and security, many of which are particularly relevant to elderly passengers. Drawing from these studies, this study proposes 11 service quality indicators: Vehicle characteristic, Bus stop characteristic, Accessibility, Convenience, Information, Staff, Safety and security, Reliability, Affordability, Facilities and support for the elderly, and post-pandemic prevention. Among these, Facilities and support for the elderly have become increasingly critical as populations age globally, requiring specialized infrastructure to address mobility limitations and ensure dignity in travel (Shrestha et al., 2017). Post-pandemic prevention measures represent an emerging priority for vulnerable elderly populations whose health risks are significantly elevated during public health crises, necessitating enhanced sanitation protocols and protective measures in public transport systems (Chuenyindee et al., 2022; Gkiotsalitis & Cats, 2021; Hsieh, 2023).

3.3.2.1 Expected service quality

Expected service quality represents the pre-consumption expectations that passengers have regarding various aspects of the public transport service. These expectations serve as standards against which the actual service performance is evaluated (Parasuraman et al., 1985). Expected service quality is influenced by various factors including past experiences, personal needs, and external communications (Teas, 1993).

In public transportation, research has shown that expected service quality is typically formed based on past experiences, word-of-mouth, personal needs, and external communications from service providers (Fu et al., 2018). Several studies have found that passengers' pre-service expectations has a direct positive influence their perceptions of the service quality actually delivered (Chonsalasin et al., 2020; Fu et al., 2018; Jomnonkwao et al., 2015; Li et al., 2019; Shen et al., 2016; Sun & Duan, 2019; Yilmaz et al., 2021; Zhang et al., 2019). Additionally, when passengers have reasonable and accurate expectations about the service, they are more likely to experience satisfaction and they can better assess whether the benefits received justify the costs incurred, several studies has demonstrated that a direct positive impact of expected service quality on both customer satisfaction and perceived value (Li et al., 2019; Shen et al., 2016; Yilmaz et al., 2021; Yuan et al., 2019; Zhang et al., 2019).

3.3.2.2 Expected service quality

Parasuraman et al. (1988) defined perceived service quality as the evaluation or judgment of the overall excellence of service delivery. It results from passengers' subjective comparison between their expectations and their perceptions of the service actually received. In public transportation research, perceived service quality has been consistently found to be a significant predictor of passenger satisfaction and loyalty (Fu et al., 2018; van Lierop et al., 2018).

Perceived Service quality is a key antecedent of perceived value (Cronin Jr et al., 2000), when passengers perceive high service quality, they tend to feel they are receiving good value for their money (Lai & Chen, 2011; Zhao et al., 2014), Moreover, perceived service quality was one of the strongest predictors of passenger satisfaction across different public transport modes (van Lierop & El-Geneidy, 2016). Several studies in the public transport industry have consistently shown that perceived service quality has a direct positive influence both on perceived value and customer satisfaction (Arancibia et al., 2025; Chonsalasin et al., 2020; Fu, 2022; Li et al., 2019; Sun & Duan, 2019; Wonglakorn et al., 2021; Yilmaz et al., 2021; Zhang et al., 2019). Furthermore, when passengers perceive high service quality, they develop greater trust in the public transportation agency (Webb, 2010; Zhao et al., 2014), as they believe the agency is capable of delivering consistent and dependable service. Numerous studies have confirmed that direct positive impact of perceived service quality on customer trust (Agung Kresnamurti Rivai P et al., 2020; Kospandani & Wahyudi, 2021; Wonglakorn et al., 2021).

3.3.3 Perceived value

Perceived value stems from a trade-off between perceived benefits and perceived costs (Zeithaml et al., 1988). In public transportation, perceived benefits are based on passengers' tastes, circumstances, and preferences, while perceived costs encompass both monetary and non-monetary sacrifices (Webb, 2010). Passengers who perceive greater value from the service report higher satisfaction levels (Fu et al., 2018; Lai & Chen, 2011; Zhang et al., 2019).

Moreover, perceived value has been found to have both direct and indirect effects on loyalty in public transportation contexts (Lai & Chen, 2011; Zhao et al., 2014). Studies found that perceived value has been a direct positive influence on both satisfaction and loyalty in various public transport contexts (Arancibia et al., 2025; Chonsalasin et al., 2020; Jomnonkwao et al., 2015; Lai & Chen, 2011; Wonglakorn et al., 2021; Zhao et al., 2014).

3.3.4 Passenger satisfaction

Satisfaction represents the affective response resulting from the evaluation of the discrepancy between prior expectations and perceived performance (Oliver, 1980). In public transportation, satisfaction refers to a passenger's level of contentment or discontentment with the service (Lu & Lu, 2009) and is often measured according to the overall customer' experience (Morfoulaki et al., 2010). Satisfaction has been consistently found to mediate the relationship between service quality and loyalty in public transport research (Chou & Kim, 2009; van Lierop & El-Geneidy, 2016). Particularly, de Oña (2021) conducted groundbreaking research on satisfaction's mediating role between service quality and loyalty, finding that the complete mediation model clearly outperformed the partial mediation model confirming that satisfaction fully mediates this relationship. Studies found that satisfaction has been a direct positive influence on loyalty as a mediator in various public transport contexts

(Allen et al., 2020; Allen, Muñoz, & Ortúzar, 2019; Arancibia et al., 2025; Chonsalasin et al., 2020; de Oña, 2021; Esmailpour et al., 2022; Fu, 2022; Hamzah et al., 2023; Hizam et al., 2021; Hsieh, 2023; Le et al., 2020; Li et al., 2019; Li et al., 2018; Nguyen-Phuoc et al., 2021; Ruiz-Padillo et al., 2024; Sun & Duan, 2019; Vicente et al., 2020; Wang et al., 2020; Wonglakorn et al., 2021; Yilmaz et al., 2021; Yuan et al., 2019; Zhang et al., 2019).

Furthermore, satisfaction contributes to the development of trust in service relationships (Garbarino & Johnson, 1999). In public transportation contexts, passengers who are satisfied with the service are more likely to trust the transport provider, Studies by Chonsalasin et al. (2020) and Kospandani and Wahyudi (2021) found that satisfaction has been a direct positive influence on trust.

3.3.5 Passenger trust

Trust refers to a customer's confidence in a service provider's reliability and integrity (Morgan & Hunt, 1994). In public transportation, trust reflects passengers' confidence that the transport provider will consistently deliver reliable and quality service and remain loyal even when faced with occasional service problems (Webb, 2010; Zhao et al., 2014), Moreover, Trust has been identified as an important precursor to loyalty, as it reduces uncertainty and vulnerability in service relationships (Sirdeshmukh et al., 2002; Wen et al., 2005). Studies found that trust has been a direct positive influence on loyalty (Agung Kresnamurti Rivai P et al., 2020; Chonsalasin et al., 2020; Kospandani & Wahyudi, 2021; Wonglakorn et al., 2021).

3.3.6 Passenger commitment

Commitment refers to a customer's emotional attachment to a service provider (Allen & Meyer, 1990). It represents a psychological bond that motivates the customer to maintain a relationship with the provider (Morgan & Hunt, 1994). In public transportation, Commitment is closely related to the concept of involvement, which has been found to significantly affect behavioral intentions (Machado-León et al., 2016; Olsen, 2007). Passengers who feel emotionally committed to using public transport are more likely to continue using it and recommend it to others (Lai & Chen, 2011; van Lierop et al., 2018). Studies in marketing and public transportation context consistently found that commitment has been a direct positive influence on loyalty (Chen, 2012; Chonsalasin et al., 2020; Li, 2011; Wonglakorn et al., 2021).

3.3.7 Alternatives attractiveness

Alternatives attractiveness refers to passengers' perceptions regarding the availability and appeal of competing transportation options (Jones et al., 2000). In public transportation, alternatives typically include private modes such as cars and motorcycles, as well as other public transport services. When passengers perceive alternative transportation modes as more attractive, they are less likely to be loyal to public transportation (Jen & Hu, 2003; Li et al., 2018). This negative relationship has been confirmed that in various studies, suggesting that public transportation agencies need to reduce the alternatives attractiveness or increase the relative appeal of their services to enhance loyalty (De Oña et al., 2016; Esmailpour et al., 2022; Li et al., 2018; Machado et al., 2018).

3.3.8 Switching costs

Switching costs refer to the financial, psychological, or emotional costs associated with changing from one service provider to another (Porter & Strategy, 1980). Higher switching costs tend to discourage customers from switching to alternative service providers, thereby increasing customer retention even when satisfaction is low (Jones et al., 2000). In public transportation context, These costs can be financial (e.g., the cost of purchasing a car), psychological (e.g., the effort of learning a new route), or emotional (e.g., breaking a habit) (Li et al., 2018), several studies have shown that switching costs directly negatively influence on loyalty (Chonsalasin et al., 2020; Esmailpour et al., 2022; Li et al., 2018; Wonglakorn et al., 2021).

Table 3.1 Summary of different structural factors influence of loyalty in previous transportation studies

Author(s) / Year	Mode / Location	Elderly group	Core variables		Other variables						
			Loyalty	Satisfaction	Perceived service quality	Expected service quality	Perceived value	Trust	Commitment	Alternative attractiveness	Switching costs
This Study	Public transport / Thailand	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Arancibia et al. (2025)	Bus and metro / Chile	-	✓	✓	✓	-	✓	-	-	-	-
Tran-Thi et al. (2024)	Bus / Vietnam	-	✓	-	✓	-	✓	-	-	-	-
Ruiz-Padillo et al. (2024)	Bus / Brazil	-	✓	✓	✓	-	-	-	-	-	-
Hamzah et al. (2023)	Bus / Malaysia	-	✓	✓	✓	-	-	-	-	-	-
Hsieh (2023)	Bus / Taiwan	-	✓	✓	✓	-	-	-	-	-	-
Esmailpour et al. (2022)	Bus / Iran	-	✓	✓	✓	-	-	-	-	✓	✓
Fu (2022)	Bus / China	-	✓	✓	✓	-	✓	-	-	-	-
Hizam et al. (2021)	Rail / Malaysia	-	✓	✓	✓	-	-	-	-	-	-
de Oña (2021)	Metro / European	-	✓	✓	✓	-	-	-	-	-	-
Wonglakorn et al. (2021)	Urban rail / Thailand	-	✓	✓	✓	-	✓	✓	✓	-	✓
Nguyen-Phuoc et al. (2021)	Bus / Vietnam	-	✓	✓	✓	-	-	-	-	-	-
Yilmaz et al. (2021)	Light rail / Turkey	-	✓	✓	✓	✓	✓	-	-	-	-
Chonsalasin et al. (2020)	Air transport / Thailand	-	✓	✓	✓	✓	✓	✓	✓	✓	✓
Vicente et al. (2020)	Metro / Portugal	-	✓	✓	✓	-	-	-	-	-	-
Le et al. (2020)	Bus and train / USA	-	✓	✓	✓	-	-	-	-	-	-
Wang et al. (2020)	Urban rail / China	-	✓	✓	✓	-	-	-	-	-	-
Allen et al. (2020)	Rail / Italy	-	✓	✓	✓	-	-	-	-	-	-
Yuan et al. (2019)	Bus / China	✓	✓	✓	✓	✓	✓	-	-	-	-
Allen, Muñoz and Ortúzar (2019)	Bus / Latin America	-	✓	✓	✓	-	-	-	-	-	-
Zhang et al. (2019)	Public transport / China	-	✓	✓	✓	✓	✓	-	-	-	-
Sun and Duan (2019)	Bus / China	-	✓	✓	✓	✓	✓	-	-	-	-
Li et al. (2019)	Bus / China	-	✓	✓	✓	✓	✓	-	-	-	-
Li et al. (2018)	Public transport / China	-	✓	✓	✓	-	-	-	-	✓	✓
Fu et al. (2018)	Bus / China	-	✓	✓	✓	✓	✓	-	-	-	-

Note: "✓" means variables that were included in the studies.

3.4 Materials and methods

3.4.1 Data collection and reliability

The study conducted face-to-face interviews to gather data. Prior to each interview, researchers explained the study objectives to potential participants and proceeded only with those who expressed comfort with the questioning process. Data collection, which took place between February and March 2024, targeted elderly citizens who utilized public transportation services. The study focused on regional public transportation systems which share similar characteristics, with interviews conducted primarily at transit stations and within community settings where substantial elderly populations resided.

A total sample of 2,000 participants was recruited, covering all five main regions of Thailand: Bangkok and its vicinity, the North, the South, the Central, and the Northeast regions. To ensure balanced geographical representation, the sample was distributed equally with 400 participants from each region. Furthermore, within each region, data was collected from both urban and rural areas to capture a comprehensive cross-section of the elderly population.

For this research, a specialized questionnaire was developed and customized to address the specific context of elderly public transportation users in Thailand. The measurement instrument incorporated nine fundamental constructs: Expected service quality, Perceived service quality, Perceived value, Passenger satisfaction, Passenger trust, Passenger commitment, Alternative attractiveness, Switching costs, and Passenger loyalty. These constructs were operationalized through 48 distinct indicators, with participants responding on a 7-point Likert scale ranging from 1 (Strongly Disagree) to 7 (Strongly Agree).

The 7-point scale was selected based on its optimal balance between measurement precision and respondent usability, providing superior discrimination capability over 5-point scales by offering more response varieties that increase the probability of meeting respondents' objective reality while eliminating forced choice dilemmas between equally undesirable points, yet avoiding the cognitive burden and complexity associated with 9-point or longer scales that can overwhelm respondents with excessive options (Joshi et al., 2015). This is particularly important for elderly populations who may experience decision fatigue with excessive response options yet require sufficient nuance to express complex perceptions about service quality and loyalty. Recent studies on Thai elderly passengers' transportation behavior have confirmed the effectiveness of 7-point scales in capturing multidimensional attitudes toward technology acceptance and behavioral intentions in transportation contexts (Dangbut et al., 2024; Watcharamaisakul et al., 2025).

To ensure scientific integrity, the instrument underwent rigorous validation procedures before deployment. Five subject matter experts in public transportation evaluated the content validity using the Index of Item Objective Congruency (IOC) methodology, with only questions achieving an IOC score above 0.50 being preserved in the final instrument. Following this expert assessment, the questionnaire was further refined through a pilot test involving 50 participants. Based on the pilot results and expert feedback, final modifications were made to optimize clarity and comprehension for the elderly respondents.

According to Kline (2015), for data to be considered normally distributed and suitable for structural equation modeling using maximum likelihood estimation, skewness values should be less than 3.0 and kurtosis values should be less than 10.0. The analysis confirms that all indicators in this study fall well within these acceptable ranges, with skewness values ranging from -0.408 to 0.897 and kurtosis values ranging from -0.391 to 2.103, indicating appropriate data distribution for further analysis. The detailed descriptive statistics, including means, standard deviations, skewness, kurtosis, and reliability coefficients for all measurement items are presented in Table 3.2.

The 48 indicators mentioned above include multiple observed variables for each of the 11 service quality dimensions. The detailed questionnaire items and their descriptions are provided in Appendix 3.1. Composite scores for each dimension (EX1–EX11 for expected service quality and PE1–PE11 for perceived service quality) were derived by calculating the mean scores of the observed variables within each respective dimension. This aggregation approach enables the examination of service quality expectations and perceptions at the dimensional level while preserving the richness of the underlying measurement structure.

Table 3.2 Descriptive statistical summary

Source	Item	Measures	Mean	SD	SK	KU
		Expected service quality (Cronbach's α = 0.969)				
	EX1	Vehicle characteristic	5.350	0.738	0.576	0.111
	EX2	Bus stop characteristic	5.301	0.789	0.720	0.087
	EX3	Accessibility	5.296	0.772	0.780	0.103
	EX4	Convenience	5.280	0.852	0.880	-0.112
Bakar et al. (2022), Chaisomboon et al. (2020), Lan et al. (2022)	EX5	Information	5.356	0.828	0.589	-0.132
	EX6	Staff	5.470	0.804	0.774	-0.322
	EX7	Safety and security	5.330	0.819	0.823	-0.074
	EX8	Reliability	5.402	0.782	0.600	-0.046
	EX9	Affordability	5.425	0.860	0.575	-0.348
Shrestha et al. (2017)	EX10	Facilities and support for the elderly	5.601	0.768	-0.073	0.722
Chuenyindee et al. (2022), Gkiotsalitis and Cats (2021), Hsieh (2023)	EX11	Post-pandemic prevention	5.300	0.811	0.550	0.392
		Perceived service quality (Cronbach's α = 0.949)				
	PE1	Vehicle characteristic	4.923	0.633	0.520	1.530
	PE2	Bus stop characteristic	4.968	0.631	0.654	1.641
	PE3	Accessibility	4.995	0.651	0.600	1.776
	PE4	Convenience	4.985	0.711	0.778	1.347
Bakar et al. (2022), Chaisomboon et al. (2020), Lan et al. (2022)	PE5	Information	5.034	0.681	0.013	1.499
	PE6	Staff	5.392	0.740	0.547	0.492
	PE7	Safety and security	4.908	0.694	0.897	0.773
	PE8	Reliability	5.008	0.682	0.538	1.507
	PE9	Affordability	5.160	0.756	0.528	0.726

Note: EX1-EX11 and PE1-PE11 represent composite scores calculated as mean values of observed variables for each service quality dimension. Detailed questionnaire items are presented in Appendix 3.1. X=Mean, SD=Standard deviation, SK=Skewness, KU = Kurtosis.

Table 3.2 Descriptive statistical summary (Continued)

Source	Item	Measures	Mean	SD	SK	KU
Shrestha et al. (2017)	PE10	Facilities and support for the elderly	4.939	0.667	0.030	2.103
Chuenyindee et al. (2022), Gkiotsalitis and Cats (2021), Hsieh (2023)	PE11	Post-pandemic prevention	4.869	0.672	0.237	1.578
		Perceived value (Cronbach's α = 0.880)				
Jomnonkwao et al. (2015), Yuan et al. (2019)	PV1	I know that the service is worth the time and money spent.	5.043	0.901	0.662	0.208
	PV2	I know that the service is satisfactory and reasonably priced.	5.044	0.905	0.612	0.120
	PV3	I think public transport offers better value than other transportation modes.	5.058	0.914	0.604	0.219
		Passenger satisfaction (Cronbach's α = 0.785)				
Esmailpour et al. (2022), Jomnonkwao et al. (2015)	SA1	I am very happy to use public transport.	5.186	0.931	-0.105	-0.380
	SA2	The quality of public bus services is as I expected.	5.156	0.924	-0.014	-0.364
	SA3	The quality of public transport services exceeds my expectations.	5.164	0.935	0.018	-0.391
	SA4	The quality of public transport services is as my dream service level.	5.045	0.949	-0.408	0.630
	SA5	Overall, I am satisfied with the quality of public transport services.	4.948	0.817	0.432	0.602
		Passenger trust (Cronbach's α = 0.881)				
Chonsalasin et al. (2020), Jomnonkwao et al. (2015), Wonglakorn et al. (2021)	PT1	I believe that public transport operators provide the best service.	5.016	0.853	0.556	0.299
	PT2	I can always trust public transport operators.	4.996	0.868	0.513	0.161
	PT3	Public transport operators know what to do to satisfy customers.	5.008	0.878	0.584	0.356
	PT4	Public transport operators are very honest.	5.052	0.867	0.577	0.188
		Passenger commitment (Cronbach's α = 0.865)				
Chonsalasin et al. (2020), Jomnonkwao et al. (2015), Wonglakorn et al. (2021)	PC1	I am proud to use public transport.	4.909	0.883	0.217	0.832
	PC2	I care about the long-term success of public transport.	4.966	0.889	0.185	1.492
	PC3	I am very committed to using public transport.	4.938	0.873	0.364	0.669
	PC4	I think public transport is an essential part of the public transportation system.	5.006	0.875	0.521	0.371

Note: EX1-EX11 and PE1-PE11 represent composite scores calculated as mean values of observed variables for each service quality dimension. Detailed questionnaire items are presented in Appendix 3.1. X=Mean, SD=Standard deviation, SK=Skewness, KU = Kurtosis.

Table 3.2 Descriptive statistical summary (Continued)

Source	Item	Measures	Mean	SD	SK	KU
		Alternative attractiveness (Cronbach's α = 0.812)				
Jomnonkwao et al. (2015), Li et al. (2018)	AA1	I think other transportation modes give me a better image than public transport.	4.757	0.795	0.073	0.985
	AA2	I think other transportation modes make me happier than public transport.	4.715	0.756	-0.167	2.096
	AA3	I am pleased to switch to other transportation modes.	4.682	0.803	-0.050	1.985
		Switching costs (Cronbach's α = 0.787)				
Jomnonkwao et al. (2015), Wonglakorn et al. (2021)	SC1	I am willing to spend more time finding a better transport service.	4.865	0.987	-0.062	-0.079
	SC2	I am willing to pay more for better transport service.	4.934	1.014	-0.332	0.569
	SC3	Switching to better transport service requires significant expense.	4.800	0.991	-0.307	0.785
		Passenger loyalty (Cronbach's α = 0.869)				
Esmailpour et al. (2022), Jomnonkwao et al. (2015), Yuan et al. (2019)	PL1	I will promote my close ones to using public transport.	4.998	0.855	0.547	0.297
	PL2	I will use public transport for my next trip.	4.990	0.839	0.462	0.296
	PL3	I will continue using public transport if the price and quality remain the same.	5.019	0.848	0.580	0.307
	PL4	I will continue using public transport if it reaches my desired destinations.	4.995	0.889	0.472	0.241

Note: EX1-EX11 and PE1-PE11 represent composite scores calculated as mean values of observed variables for each service quality dimension. Detailed questionnaire items are presented in Appendix 3.1. X=Mean, SD=Standard deviation, SK=Skewness, KU = Kurtosis.

3.4.2 Data analysis

3.4.2.1 Expected service quality

Structural Equation Modeling (SEM) is a comprehensive statistical approach for examining relationships among multiple variables simultaneously, allowing researchers to test complex theoretical models with both observed and latent variables (Hair et al., 2014). This methodology combines factor analysis and multiple regression techniques, making it particularly suitable for evaluating both measurement and structural relationships in theories involving multiple constructs (Kline, 2015).

The superiority of SEM becomes evident when compared to traditional analytical approaches. A comprehensive literature review reveals SEM's dominance in this field, being employed in 17 out of 30 studies in high-income countries and 27 out of 30 studies in low- and middle-income countries (Pham et al., 2023), reflecting its unique capabilities that effectively address the limitations of alternative methods. Unlike linear regression models that examine relationships individually, SEM simultaneously evaluates both measurement and structural relationships while accounting for measurement error (Hair et al., 2014; Kline, 2015). Regression and logit model approaches are fundamentally limited in handling complex interdependencies between service quality, satisfaction, trust, and loyalty. For instance, studies by Figler et al. (2011) and Kim and Ulfarsson (2012) could examine direct effects but could not account for mediating effects crucial for understanding complete loyalty formation processes. Similarly, factor analysis approaches (EFA and CFA), while valuable for validating measurement models, are insufficient for testing structural relationships between constructs. Studies employing only CFA approaches, such as Jen and Hu (2003) and Tao et al. (2017), could confirm construct dimensionality but could not examine causal pathways essential for understanding loyalty formation. Descriptive statistical approaches used by Burkhardt (2003), provide insights into individual variables but lack the capability to test theoretical relationships and causal mechanisms.

Maximum Likelihood (ML) estimation, the most widely used approach within SEM, was established by statisticians in the early to mid-20th century.

Jöreskog (1970) developed the application of ML estimation for factor analysis models, which became fundamental to SEM development, while Bollen (1989) provided comprehensive treatment of SEM methodology, establishing it as a rigorous approach for testing complex theoretical relationships.

3.4.2.2 Model fit criteria

Evaluating the fit of structural equation models requires several key indicators, each with recommended thresholds to ensure adequacy. The chi-square statistic divided by the degrees of freedom (χ^2/df) should ideally be less than 3 (Kline, 2015), however some researchers suggest that values up to 5 can still indicate reasonable fit (Marsh & Hocevar, 1985). The root mean square error of approximation (RMSEA) should be below 0.06 for excellent fit, although values up to 0.08 are still considered acceptable (Hu & Bentler, 1999). The standardized root mean square residual (SRMR) should be under 0.08 to be considered a good fit (Hu & Bentler, 1999). For the incremental fit indices, the Tucker-Lewis Index (Zhou et al.) values above 0.95 are preferred, with those over 0.90 still deemed acceptable (Bentler & Bonett, 1980). Similarly, the comparative fit index (CFI) should exceed 0.95 for excellent fit, with values over 0.90 being acceptable (Bentler, 1990).

In this study, we developed a comprehensive structural equation model comprising both measurement and structural components. The analysis was executed using Mplus software version 7.2, applying maximum likelihood estimation methods to evaluate the hypothesized relationships between variables.

3.4.3 Research hypotheses

Based on the theoretical framework established in Section 2, fourteen hypotheses were developed to examine relationships among the nine constructs, organized into four theoretical pathways:

1) Service Quality Expectations and Perceptions (H1-H6): Expected service quality, representing pre-consumption standards for evaluating actual performance, particularly influences elderly passengers' subsequent perceptions and satisfaction. Therefore, the following hypotheses are proposed:

H1: Expected service quality positively impacts perceived service quality.

H2: Expected service quality positively impacts passenger satisfaction.

H3: Expected service quality positively impacts perceived value.

Perceived service quality, reflecting evaluation of actual service delivery across multiple dimensions including traditional aspects and post-pandemic safety measures, drives value, satisfaction, and trust formation. Accordingly, the proposed hypotheses are:

H4: Perceived service quality positively impacts perceived value.

H5: Perceived service quality positively impacts passenger satisfaction.

H6: Perceived service quality positively impacts passenger trust.

2) Value and Satisfaction Pathways (H7-H10): Perceived value represents benefit-cost trade-offs while satisfaction reflects overall service contentment, both serving as key mediators in loyalty formation. Thus, the following hypotheses are formulated:

H7: Perceived value positively impacts passenger satisfaction.

H8: Perceived value positively impacts passenger loyalty.

H9: Passenger satisfaction positively impacts passenger trust.

H10: Passenger satisfaction positively impacts passenger loyalty.

3) Relationship Factors (H11-H12): Trust and commitment represent psychological bonds between passengers and service providers, particularly crucial for elderly users facing uncertainty about service reliability and safety. Hence, the following hypotheses are proposed:

H11: Passenger trust positively impacts passenger loyalty.

H12: Passenger commitment positively impacts passenger loyalty.

4) Switching Behavior Factors (H13-H14): Alternative attractiveness and switching costs reflect competitive dynamics and change barriers, especially relevant for elderly passengers who may face unique challenges in transportation mode changes. Therefore, the final hypotheses are:

H13: Alternative attractiveness negatively impacts passenger loyalty.

H14: Switching costs negatively impact passenger loyalty.

3.5 Results

3.5.1 Descriptive analysis

The demographic characteristics of the 2,000 elderly public transport users in Thailand presented in Table 3.3 reveal a slightly higher proportion of males (52.30%) than females (47.70%), with most respondents being married (61.10%). Age distribution shows a concentration in the young-old category (60-69 years) at 70.0%, followed by 70-79 years (21.4%) and 80+ years (8.6%). Educational attainment varies, with 55.80% having less than a bachelor's degree, 20.80% holding a bachelor's degree, and 23.40% having completed higher education. Income distribution is relatively balanced across categories, with 25.4% earning less than 10,000 Thai Baht (THB) monthly, 26.5% earning 10,000-19,999 THB, 29.6% earning 20,000-29,999 THB, and 18.5% earning 30,000+ THB. Most respondents use public transport infrequently, with 35.10% traveling less than once a month and 30.40% traveling once monthly, while only 3.00% use it daily. The primary travel purposes include leisure trips (38.50%), shopping (14.20%), activities (13.40%), work/business (12.00%), medical appointments (11.00%), and other purposes (10.90%).

Table 3.3 Demographics of the participants

Demographic	Category	Frequency	Percent
Gender	Male	1046	52.30
	Female	954	47.70
Status	Single	323	16.15
	Married	1222	61.10
	Others	455	22.75
Age	60–69 years old	1399	70.0
	70–79 years old	429	21.4
	80 years old and above	172	8.6
Education	Less than bachelor's degree	1115	55.80
	Bachelor's degree	415	20.80
	Higher bachelor’s degree	470	23.40
Income	Less than 10,000 (THB/Month)	507	25.4
	>10,000–19,999 (THB/Month)	532	26.5
	>20,000–29,999 (THB/Month)	591	29.6
	30,000 and above (THB/Month)	370	18.5

Note: THB = Thai Baht.

Table 3.3 Demographics of the participants (Continued)

Demographic	Category	Frequency	Percent
Travel frequency	Daily	60	3.00
	3-5 times a week	175	8.80
	1-2 times a week	220	11.00
	Twice a month	234	11.70
	Once a month	608	30.40
	Less than once a month	703	35.10
Travel purpose	Work/Business	240	12.00
	Travel	770	38.50
	Shopping	285	14.20
	Activities	267	13.40
	Hospital/Medical appointments	220	11.00
	Others	218	10.90

Note: THB = Thai Baht.

The 48 indicators underwent comprehensive statistical examination, including assessment of central tendency measures, standard deviation, skewness, and kurtosis coefficients (details presented in Table 3.2). These indicators were organized into nine distinct construct categories as follows.

1) Expected service quality indicators (11 variables) with mean values ranging from 5.280 to 5.601. The indicator with the highest average was EX10: Facilities and support for the elderly (mean = 5.601; SD = 0.768), while the lowest was EX4: Convenience (mean = 5.280; SD = 0.852).

2) Perceived service quality indicators (11 variables) with mean values ranging from 4.869 to 5.392. The indicator with the highest average was PE6: Staff (mean = 5.392; SD = 0.740), while the lowest was PE11: Post-pandemic prevention (mean = 4.869; SD = 0.672).

3) Perceived value indicators (three variables) with mean values ranging from 5.043 to 5.058. The indicator with the highest average was PV3: I think public transport offers better value than other transportation modes (mean = 5.058; SD = 0.914), while the lowest was PV1: I know that the service is worth the time and money spent (mean = 5.043; SD = 0.901).

4) Passenger satisfaction indicators (five variables) with mean values ranging from 4.948 to 5.186. The indicator with the highest average was SA1: I am very

happy to use public transport (mean = 5.186; SD = 0.931), while the lowest was SA5: Overall, I am satisfied with the quality of public transport services (mean = 4.948; SD = 0.817).

5) Passenger trust indicators (four variables) with mean values ranging from 4.996 to 5.052. The indicator with the highest average was PT4: Public transport operators are very honest (mean = 5.052; SD = 0.867), while the lowest was PT2: I can always trust public transport operators (mean = 4.996; SD = 0.868).

6) Passenger commitment indicators (four variables) with mean values ranging from 4.909 to 5.006. The indicator with the highest average was PC4: I think public transport are an essential part of the public transportation system (mean = 5.006; SD = 0.875), while the lowest was PC1: I am proud to use public transport (mean = 4.909; SD = 0.883).

7) Alternative attractiveness indicators (three variables) with mean values ranging from 4.682 to 4.757. The indicator with the highest average was AA1: I think other transportation modes give me a better image than public transport (mean = 4.757; SD = 0.795), while the lowest was AA3: I am pleased to switch to other transportation modes (mean = 4.682; SD = 0.803).

8) Switching costs indicators (three variables) with mean values ranging from 4.800 to 4.934. The indicator with the highest average was SC2: I am willing to pay more for better transport service (mean = 4.934; SD = 1.014), while the lowest was SC3: Switching to better transport service requires significant expense (mean = 4.800; SD = 0.991).

9) Passenger loyalty indicators (four variables) with mean values ranging from 4.990 to 5.019. The indicator with the highest average was PL3: I will continue using public transport if the price and quality remain the same (mean = 5.019; SD = 0.848), while the lowest was PL2: I will use public transport for my next trip (mean = 4.990; SD = 0.839).

3.5.2 Measurement model

The model fit results indicate generally good fit with the empirical data. According to the criteria outlined in section 3.2.1, several key indicators were examined. Although the χ^2/df ratio (3.900) slightly exceeds the ideal threshold of 3, this is common in large samples. The RMSEA value (0.038) is well below the critical threshold of 0.06, suggesting an excellent fit in terms of model parsimony. Similarly, the SRMR value (0.053) is below the 0.08 threshold, indicating good fit of the residuals. The incremental fit indices, CFI (0.957) and TLI (0.952), both exceed the 0.95 threshold, further confirming excellent model fit. Overall, these results demonstrate that the measurement model adequately represents the observed data.

The measurement model was subjected to validation through structural equation modeling. Convergent validity was assessed using factor loadings, average variance extracted (AVE), and composite reliability (CR). As shown in Table 3.4.

Table 3.4 Parameter estimation of measurement model in SEM

Constructs and Indicators	Standardized Loading	Standard Error	t-value	R^2
Expected service quality (AVE = 0.677, CR = 0.958)				
EX1	0.774	0.010	80.567**	0.599
EX2	0.866	0.006	143.456**	0.751
EX3	0.864	0.006	139.752**	0.747
EX4	0.888	0.005	169.917**	0.789
EX5	0.836	0.007	118.975**	0.699
EX6	0.842	0.007	116.221**	0.709
EX7	0.800	0.009	93.109**	0.640
EX8	0.812	0.008	100.212**	0.659
EX9	0.829	0.008	109.427**	0.687
EX10	0.712	0.011	63.477**	0.508
EX11	0.812	0.008	102.673**	0.659
Perceived service quality (AVE = 0.540, CR = 0.928)				
PE1	0.694	0.012	58.765**	0.482
PE2	0.754	0.010	73.490**	0.568
PE3	0.766	0.010	75.757**	0.587
PE4	0.778	0.010	80.167**	0.605
PE5	0.686	0.012	55.047**	0.470
PE6	0.778	0.010	79.032**	0.605
PE7	0.744	0.011	69.205**	0.554
PE8	0.784	0.009	83.646**	0.615
PE9	0.763	0.010	76.283**	0.582
PE10	0.679	0.013	54.008**	0.461
PE11	0.640	0.014	46.179**	0.410
Perceived value (AVE = 0.726, CR = 0.888)				
PV1	0.853	0.009	96.998**	0.728
PV2	0.856	0.008	109.134**	0.733
PV3	0.847	0.009	93.534**	0.717

Note: ** significant at $p < 0.001$; * significant at $p < 0.05$.

Table 3.4 Parameter estimation of measurement model in SEM (Continued)

Constructs and Indicators	Standardized Loading	Standard Error	t-value	R^2
Passenger satisfaction (AVE = 0.490, CR = 0.821)				
SA1	0.795	0.010	76.698**	0.631
SA2	0.777	0.013	60.695**	0.604
SA3	0.506	0.017	29.029**	0.256
SA4	0.507	0.017	29.244**	0.257
SA5	0.836	0.015	55.362**	0.699
Passenger trust (AVE = 0.646, CR = 0.880)				
PT1	0.807	0.009	90.296**	0.651
PT2	0.800	0.010	82.619**	0.640
PT3	0.829	0.009	96.045**	0.687
PT4	0.779	0.010	76.836**	0.608
Passenger commitment (AVE = 0.577, CR = 0.845)				
PC1	0.760	0.011	67.281**	0.577
PC2	0.759	0.012	63.401**	0.576
PC3	0.764	0.011	67.183**	0.584
PC4	0.755	0.011	66.764**	0.570
Alternative attractiveness (AVE = 0.531, CR = 0.771)				
AA1	0.646	0.020	32.807**	0.418
AA2	0.725	0.018	39.979**	0.525
AA3	0.807	0.018	45.737**	0.652
Switching costs (AVE = 0.551, CR = 0.786)				
SC1	0.737	0.014	51.502**	0.543
SC2	0.754	0.014	53.543**	0.569
SC3	0.736	0.015	50.772**	0.542
Passenger loyalty (AVE = 0.601, CR = 0.858)				
PL1	0.784	0.010	77.780**	0.615
PL2	0.792	0.010	79.759**	0.628
PL3	0.786	0.012	77.678**	0.618
PL4	0.739	0.010	63.508**	0.546

Note: ** significant at $p < 0.001$; * significant at $p < 0.05$.

Analysis of the measurement model supports a nine-factor solution comprising one endogenous construct (Passenger loyalty) and eight exogenous constructs (Expected service quality, Perceived service quality, Perceived value, Passenger satisfaction, Passenger trust, Passenger commitment, Alternative attractiveness, and Switching costs). All measurement relationships are statistically significant ($p < 0.001$), confirming the factorial validity of the proposed measurement model. The measurement properties of these variables are described in detail below:

Expected service quality demonstrates strong internal consistency (CR = 0.958) with all eleven indicators showing high factor loadings (0.712-0.888), indicating that elderly passengers form clear expectations across all service dimensions, with Convenience (EX4, λ = 0.888) and Bus Stop Characteristics (EX2, λ = 0.866) emerging as particularly important indicators.

Perceived service quality exhibits robust reliability (CR = 0.928) with factor loadings ranging from 0.640 to 0.784. Reliability (PE8, λ = 0.784), Convenience (PE4, λ = 0.778), and Staff (PE6, λ = 0.778) are the strongest indicators, reflecting elderly passengers' emphasis on consistent service, ease of use, and staff interactions.

Perceived value shows excellent psychometric properties (AVE = 0.726, CR = 0.888) with nearly equal loadings across all three indicators (0.847-0.856), suggesting a balanced assessment of monetary and non-monetary value perceptions among elderly passengers.

Passenger satisfaction demonstrates acceptable reliability (CR = 0.821) despite somewhat lower convergent validity (AVE = 0.490). Overall satisfaction (SA5, λ = 0.836) and happiness with service (SA1, λ = 0.795) are the strongest indicators, while expectation-related indicators (SA3, SA4) show relatively lower loadings.

Passenger trust exhibits strong measurement properties (AVE = 0.646, CR = 0.880) with all indicators loading highly (0.779-0.829), particularly the belief that operators understand customer needs (PT3, λ = 0.829), indicating the importance of perceived competence in trust formation.

Passenger commitment shows good reliability (CR = 0.845) with consistent loadings across all four indicators (0.755-0.764), suggesting relatively equal importance of pride, care, commitment, and belief in the essential nature of public transportation.

Alternatives attractiveness, though having the lowest composite reliability (CR = 0.771), still demonstrates acceptable measurement properties, with the willingness to switch (AA3, λ = 0.807) being the strongest indicator of perceived alternatives.

Switching costs shows satisfactory convergent validity (AVE = 0.551) and reliability (CR = 0.786), with willingness to pay more for better service (SC2, λ = 0.754) being the primary indicator.

Passenger loyalty demonstrates strong psychometric properties (AVE = 0.601, CR = 0.858) with all indicators loading highly (0.739-0.792), particularly the intention to use public transport for the next trip (PL2, λ = 0.792), highlighting the behavioral intention aspect of loyalty.

3.5.3 Structural equation model

According to the hypothetical model of the research framework, structural equation modeling was performed to test the relationships between constructs. Figure 3.1 presents the standardized path coefficients and significance levels for all hypothesized relationships. The model maintains good fit indices (χ^2 = 3989.689, df = 1023, χ^2/df = 3.900, RMSEA = 0.038, SRMR = 0.053, CFI = 0.957, TLI = 0.952), confirming adequate representation of the observed data. The specific path coefficients, standard errors, t-values, and hypothesis testing results are summarized in Table 3.5, which provides a comprehensive overview of the structural relationships examined in this study.

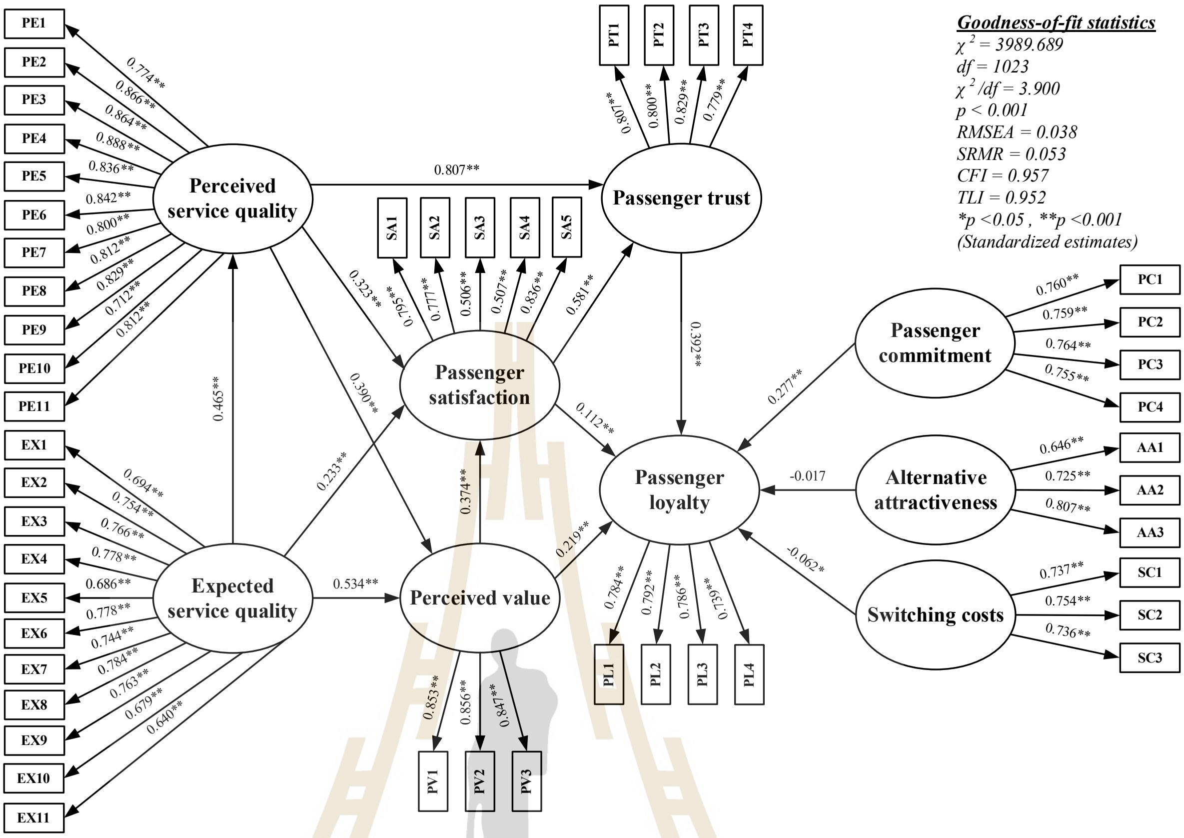

Figure 3.1 Results of hypothetical model testing

The structural model demonstrates that 13 of the 14 hypothesized relationships are statistically significant, revealing the complex dynamics influencing elderly passengers' loyalty to public transportation in Thailand. The results of hypothetical model testing are described in detail below:

Regarding service quality dimensions, expected service quality shows strong positive effects on perceived service quality (β = 0.465, $p < 0.001$), passenger satisfaction (β = 0.233, $p < 0.001$), and perceived value (β = 0.534, $p < 0.001$), supporting hypotheses H1, H2, and H3. These significant relationships highlight the crucial role of pre-service expectations in shaping elderly passengers' subsequent evaluations. Similarly, perceived service quality demonstrates substantial positive influences on perceived value (β = 0.390, $p < 0.001$), passenger satisfaction (β = 0.323, $p < 0.001$), and notably, a particularly strong effect on passenger trust (β = 0.807, $p < 0.001$), confirming hypotheses H4, H5, and H6. This underscores the pivotal role of service quality as experienced by elderly passengers in developing trust and enhancing satisfaction.

In terms of loyalty-satisfaction relationships, perceived value positively affects both passenger satisfaction (β = 0.374, $p < 0.001$) and passenger loyalty (β = 0.219, $p < 0.001$), supporting hypotheses H7 and H8. These findings indicate that when elderly passengers perceive they are receiving good value from public transportation, they experience higher satisfaction and develop stronger loyalty. Passenger satisfaction demonstrates significant positive effects on passenger trust (β = 0.581, $p < 0.001$) and passenger loyalty (β = 0.112, $p < 0.001$), supporting hypotheses H9 and H10, though the direct effect on loyalty is relatively modest compared to other predictors.

Concerning direct influences on loyalty formation, passenger trust exhibits a substantial positive effect on passenger loyalty (β = 0.392, $p < 0.001$), supporting hypothesis H11 and identifying trust as one of the strongest direct predictors of loyalty among elderly passengers. Similarly, passenger commitment shows a strong positive influence on passenger loyalty (β = 0.277, $p < 0.001$), supporting hypothesis H12 and highlighting the importance of emotional attachment in fostering continued loyalty.

Regarding competitive factors, contrary to expectations, hypothesis H13 regarding the negative effect of alternative attractiveness on passenger loyalty was not supported (β = -0.017, $p > 0.05$), suggesting that elderly passengers' loyalty to public transport is not significantly diminished by the perceived attractiveness of alternative transportation modes. Switching costs demonstrate a significant negative effect on passenger loyalty (β = -0.062, $p < 0.05$), supporting hypothesis H14, indicating that higher perceived costs of switching to alternative transportation modes reduce elderly passengers' loyalty to public transport.

Table 3.5 Results of hypothesis path analysis

Hypothesis Path	Standardized Estimate (β)	Standard Error	t-value	Result
H1: Expected service quality ⟶ Perceived service quality	0.465	0.018	26.288**	Supported
H2: Expected service quality ⟶ Passenger satisfaction	0.233	0.006	35.977**	Supported
H3: Expected service quality ⟶ Perceived value	0.534	0.018	30.188**	Supported
H4: Perceived service quality ⟶ Perceived value	0.390	0.019	20.980**	Supported
H5: Perceived service quality ⟶ Passenger satisfaction	0.323	0.010	32.026**	Supported
H6: Perceived service quality ⟶ Passenger trust	0.807	0.028	28.634**	Supported
H7: Perceived value ⟶ Passenger satisfaction	0.374	0.018	20.690**	Supported
H8: Perceived value ⟶ Passenger loyalty	0.219	0.033	6.682**	Supported
H9: Passenger satisfaction ⟶ Passenger trust	0.581	0.014	42.417**	Supported
H10: Passenger satisfaction ⟶ Passenger loyalty	0.112	0.021	5.391**	Supported
H11: Passenger trust ⟶ Passenger loyalty	0.392	0.044	8.932**	Supported
H12: Passenger commitment ⟶ Passenger loyalty	0.277	0.047	5.933**	Supported
H13: Alternative attractiveness ⟶ Passenger loyalty	-0.017	0.025	-0.707	Not Supported
H14: Switching costs ⟶ Passenger loyalty	-0.062	0.023	-2.689*	Supported

Note: ⟶ = regression on, ** significant at $p < 0.001$; * significant at $p < 0.05$.

Overall, the structural model reveals that passenger loyalty among elderly public transport users in Thailand is primarily influenced by a chain of relationships where service expectations and perceptions build trust, satisfaction, and value perceptions, which in turn foster loyalty. The strongest direct predictors of loyalty are trust, commitment, and perceived value, highlighting the importance of these psychological factors in encouraging continued use of public transportation among Thailand's elderly population.

3.6 Discussion and finding

This study investigated the determinants of public transportation loyalty among Thailand's elderly population using structural equation modeling. The findings confirm 13 of the 14 hypothesized relationships, revealing the complex mechanisms underlying loyalty formation. To systematically discuss these findings, the discussion is organized into four interrelated factor groups: (1) Service Quality-Related Factors, (2) Value and Satisfaction Factors, (3) Relationship Factors, and (4) Switching Behavior Factors.

3.6.1 Service quality-related factors

3.6.1.1 Service quality dimensions

The measurement model reveals important insights about the relative importance of different service quality dimensions for elderly passengers. For expected service quality, convenience (EX4, λ = 0.888) and bus stop characteristics (EX2, λ = 0.866) emerged as particularly important indicators. For perceived service quality, reliability (PE8, λ = 0.784), convenience (PE4, λ = 0.778), and staff behavior (PE6, λ = 0.778) are the strongest indicators.

Notably, the inclusion of specialized dimensions "Facilities and support for the elderly" and "Post-pandemic prevention" proved relevant, though with generally lower factor loadings than traditional service aspects. This suggests that while elderly-specific facilities and pandemic prevention measures are components of service quality assessments, traditional service aspects like reliability, convenience, and staff interactions remain primary concerns for elderly passengers in Thailand.

3.6.1.2 Impact of expected service quality

The findings confirm the significant role of service quality expectations in shaping elderly passengers' evaluations. The strong positive influence of expected service quality on perceived service quality (β = 0.465, $p < 0.001$) supports H1 and aligns with previous research by Chonsalasin et al. (2020), Yilmaz et al. (2021) and Zhang et al. (2019). This relationship demonstrates that elderly passengers' pre-service expectations significantly shape their perceptions of the actual service received, highlighting the importance of managing expectations in service delivery.

Expected service quality also positively influences passenger satisfaction (β = 0.233, $p < 0.001$) and perceived value (β = 0.534, $p < 0.001$), confirming

H2 and H3. These findings are consistent with research by Li et al. (2019), Yilmaz et al. (2021) and Yuan et al. (2019) underscoring the role of pre-service expectations in establishing baseline standards for evaluating service delivery. For elderly passengers in Thailand, the formation of appropriate expectations appears crucial for subsequent satisfaction and value assessments.

3.6.1.3 Impact of perceived service quality

Perceived service quality demonstrates substantial positive influences on perceived value (β = 0.390, $p < 0.001$) and passenger satisfaction (β = 0.323, $p < 0.001$), confirming H4 and H5. These findings align with research by Arancibia et al. (2025), Fu (2022), and Yilmaz et al. (2021) reinforcing the established service quality-satisfaction-loyalty and service quality-perceived value-loyalty relationships in public transportation contexts.

However, the most striking finding is the exceptionally strong effect of perceived service quality on passenger trust (β = 0.807, $p < 0.001$), confirming H6 and extending research by Agung Kresnamurti Rivai P et al. (2020), Kospandani and Wahyudi (2021) and Wonglakorn et al. (2021). This powerful relationship underscores how elderly passengers' trust is fundamentally formed through their direct evaluation of service quality dimensions. In Thailand's post-pandemic context, delivering consistent, reliable, and elderly-friendly service appears critical for establishing the trust that ultimately contributes to loyalty formation.

3.6.2 Value and satisfaction factors

3.6.2.1 Perceived value

Perceived value demonstrates significant positive effects on both passenger satisfaction (β = 0.374, $p < 0.001$) and passenger loyalty (β = 0.219, $p < 0.001$), supporting H7 and H8. These findings extend the value-satisfaction-loyalty chain identified by Arancibia et al. (2025), Hamzah et al. (2023) and Wonglakorn et al. (2021). The direct path from perceived value to loyalty (β = 0.219) represents one of the strongest direct predictors of loyalty in the model, highlighting how elderly passengers' assessment of benefits relative to costs significantly influences their continued patronage intentions.

The measurement model reveals a balanced assessment of value among elderly passengers, with nearly equal loadings across all three indicators (0.847-0.856). This suggests that elderly passengers in Thailand consider multiple dimensions of value perception, including service benefits relative to monetary costs, satisfaction with time and money spent on public transportation, and comparative value assessment between public transport and alternative modes. This balanced evaluation demonstrates that elderly passengers employ a comprehensive value framework rather than focusing solely on financial considerations when deciding on their public transportation choices.

3.6.2.2 Passenger satisfaction

Passenger satisfaction demonstrates significant positive effects on passenger trust (β = 0.581, $p < 0.001$) and passenger loyalty (β = 0.112, $p < 0.001$), supporting H9 and H10. The strong relationship between satisfaction and trust aligns with findings from Chonsalasin et al. (2020) and Kospandani and Wahyudi (2021), confirming that satisfied elderly passengers develop greater confidence in transportation providers.

However, the direct effect of satisfaction on loyalty (β = 0.112) is relatively modest compared to other predictors in the model. This finding extends de Oña (2021) research on satisfaction's mediating role, suggesting that for elderly passengers in Thailand, satisfaction may influence loyalty more strongly through trust-building mechanisms than through direct effects, given the strong relationship between satisfaction and trust (β = 0.581) and the substantial impact of trust on loyalty (β = 0.392). This nuanced relationship highlights the importance of looking beyond satisfaction to comprehensively understand loyalty formation among elderly passengers.

3.6.3 Relationship factors

3.6.3.1 Passenger trust

Trust emerged as the strongest direct predictor of loyalty in the model (β = 0.392, $p < 0.001$), supporting H11 and extending previous findings by Chonsalasin et al. (2020), Kospandani and Wahyudi (2021) and Wonglakorn et al. (2021). This powerful relationship highlights the critical importance of establishing and maintaining trust in public transportation services for elderly passengers, especially in Thailand's post-pandemic context where health and safety concerns may be heightened.

The strong measurement properties of the trust construct (AVE = 0.646, CR = 0.880) further reinforce its importance, with all indicators loading highly (0.779-0.829). Particularly notable is the belief that operators understand customer needs (PT3, λ = 0.829), indicating that perceived competence and empathy are central to trust formation among elderly passengers. This finding suggests that elderly users place significant emphasis on transportation providers' ability to recognize their specific mobility challenges and requirements. Beyond service reliability and honesty (PT1, PT2, PT4), the specialized service quality dimensions 'Facilities and support for the Elderly' and 'Post-Pandemic Prevention' play crucial roles in building trust among Thai elderly passengers, as perceived service quality strongly influences trust (β = 0.807). The provision of priority seating, assistance facilities, accessible infrastructure, and enhanced health safety protocols serves as tangible evidence that operators understand and address the unique physical limitations and health concerns of elderly riders, ultimately fostering the trust that strongly influences loyalty (β = 0.392) in Thailand's post-pandemic transportation context.

3.6.3.2 Passenger commitment

Commitment exhibited a strong positive influence on passenger loyalty (β = 0.277, $p < 0.001$), supporting H12 and aligning with research by Chonsalasin et al. (2020) and Wonglakorn et al. (2021). As the second strongest direct predictor of loyalty in the model, commitment highlights how elderly passengers' emotional attachment and dedication to public transportation significantly influence their continued patronage and recommendations to others.

The measurement model shows consistent loadings across all four commitment indicators (0.755-0.764), suggesting relatively equal importance of pride in using public transport, care about its success, personal commitment to usage, and belief in its essential nature. This balanced view of commitment indicates that elderly passengers in Thailand develop multifaceted psychological bonds with public transportation that significantly contribute to loyalty formation. The nearly identical loading values reveal that commitment among elderly passenger's manifests through both emotional attachment (pride in using public transport) and rational recognition (believing in public transport's essential role), supported by behavioral investment (personal commitment to usage) and concern for service sustainability (caring about long-term success). These four dimensions collectively form a robust psychological contract between elderly users and public transportation services, emphasizing that commitment-building strategies should address both emotional and practical aspects of the elderly passenger experience.

3.6.4 Switching behavior factors

3.6.4.1 Alternative attractiveness

Contrary to expectations, the hypothesized negative effect of alternative attractiveness on passenger loyalty was not supported (β = -0.017, $p > 0.05$), contradicting findings by Esmailpour et al. (2022) and Li et al. (2018). This unexpected result suggests that elderly passengers in Thailand may not significantly consider alternative transportation options when forming loyalty to public transit.

Several explanations are possible: First, elderly passengers may have limited viable alternatives due to physical mobility restrictions, financial constraints, or lack of access to private transportation, reflecting the transportation vulnerability commonly observed among older adults in Thailand. Second, habitual patterns of public transport use may reduce the salience of alternatives in decision-making, as elderly passengers often develop strong routines and familiarity with specific services that provide predictability and comfort. Third, the perceived risks associated with switching to unfamiliar transportation modes may outweigh potential benefits for elderly passengers, particularly in the post-pandemic context where health safety concerns, technological barriers to using newer transportation options, and anxiety about navigating unfamiliar systems create substantial psychological switching barriers that override considerations about alternative attractiveness.

3.6.4.2 Switching costs

Switching costs demonstrated a significant negative effect on passenger loyalty (β = -0.062, $p < 0.05$), supporting H14 and confirming findings by Chonsalasin et al. (2020), Esmailpour et al. (2022) and Wonglakorn et al. (2021).

Although the effect size is relatively small, the significant relationship indicates that higher perceived costs of switching to alternative transportation modes reduce elderly passengers' loyalty to public transport, potentially reflecting constraints rather than voluntary choice factors.

The measurement model shows that the willingness to pay more for better service (SC2, $\lambda = 0.754$) is the primary indicator of switching costs, suggesting that financial considerations are particularly salient in elderly passengers' switching decisions. This finding highlights the importance of maintaining competitive pricing and service quality to discourage switching behavior among price-sensitive elderly users. Despite Thailand's transition to an aging society, many elderly passengers face financial limitations from fixed retirement incomes or limited savings, making price sensitivity a critical factor in their transportation decisions. The strong loading of this financial indicator reveals that elderly passengers carefully evaluate the economic trade-offs when considering alternatives, weighing potential service improvements against additional costs. This price consciousness likely reflects broader economic vulnerabilities among Thailand's elderly population and emphasizes that public transportation providers must balance quality enhancements with affordability to retain this growing demographic segment.

3.7 Conclusions and implications

3.7.1 Research summary

This study investigated the determinants of public transportation loyalty among Thailand's elderly population from a post-pandemic perspective, addressing critical research gaps in understanding the complex mechanisms behind loyalty formation in this vital demographic. Using Structural Equation Modeling (SEM) with data from 2,000 elderly participants across all five regions of Thailand, the research examined the interrelationships among nine key constructs: Expected service quality, Perceived service quality, Perceived value, Passenger satisfaction, Passenger trust, Passenger commitment, Alternative attractiveness, Switching costs, and Passenger loyalty.

The findings confirm 13 of 14 hypothesized relationships, revealing that passenger trust (β = 0.392), passenger commitment (β = 0.277), and perceived value (β = 0.219) are the strongest direct predictors of loyalty, while perceived service quality shows an exceptionally strong effect on trust (β = 0.807). Contrary to expectations, alternative attractiveness did not significantly affect loyalty, suggesting elderly passengers' loyalty is not substantially influenced by the perceived appeal of alternative transportation modes.

The study confirmed expected service quality as a foundational element in loyalty formation, with significant direct effects on perceived service quality (β = 0.465), passenger satisfaction (β = 0.233), and perceived value (β = 0.534). These relationships highlight how pre-service expectations establish the framework for subsequent evaluations and ultimately influence loyalty through multiple pathways. While satisfaction positively affects loyalty (β = 0.112), its impact is relatively modest compared to trust, commitment, and perceived value, suggesting satisfaction alone is insufficient for fostering strong loyalty among elderly passengers.

The integration of specialized dimensions into the service quality framework, particularly "Facilities and support for the elderly" and "Post-Pandemic Prevention" proved relevant to elderly passengers' evaluations, though traditional service aspects like reliability, convenience, and staff interactions remained primary concerns. This finding emphasizes the importance of maintaining fundamental service quality while addressing elderly-specific needs and post-pandemic safety concerns.

Overall, this comprehensive investigation establishes a novel framework for understanding loyalty determinants specific to elderly passengers, highlighting the critical service quality-trust-loyalty pathway that can guide transportation providers in developing tailored strategies to enhance elderly mobility and social participation in Thailand's rapidly aging society.

3.7.2 Policy implications and recommendations

This study offers practical implications for transportation providers and policymakers seeking to enhance elderly passenger loyalty in Thailand's rapidly aging society. Currently, Thailand's public transportation system provides limited elderly-specific facilities. For vehicle characteristics, most buses lack adequate temperature control, comfortable seating arrangements, and power outlets that elderly passengers need for extended travel. Bus stop infrastructure typically offers minimal weather protection and inadequate seating, particularly challenging for elderly with mobility limitations. Regarding accessibility, while newer stations have some ramps and elevators, many older facilities remain difficult to access with poor connectivity between transportation modes. However, specific measures addressing elderly passengers' unique vulnerabilities during the pandemic were limited, with many older adults struggling to access protective equipment and adapt to new safety protocols due to economic constraints and limited digital literacy.

For elderly-specific accommodations (corresponding to EX10-PE10 in Appendix 3.1), Thailand's system currently offers basic priority seating and minimal handrails, but lacks comprehensive features like clear audio-visual information systems, adequate assistance channels, and properly designed boarding facilities for those with mobility devices. Staff training for elderly assistance remains limited and inconsistent across transportation modes.

Following the COVID-19 pandemic (corresponding to EX11-PE11 in Appendix 3.1), basic measures were implemented including periodic cleaning, limited mask policies, and some ventilation improvements. However, comprehensive prevention systems like consistent screening procedures, ongoing prevention education, and specialized protections for vulnerable elderly passengers were inadequately developed and inconsistently applied. Many elderly passengers struggled with adapting to rapidly changing protocols due to limited communication channels specifically designed for their needs.

Building upon this existing infrastructure while addressing identified gaps, the results revealed passenger trust as the strongest direct predictor of loyalty, followed by passenger commitment and perceived value. Based on these priority factors, transportation providers should implement trust-building initiatives through transparent communication about service changes and disruptions. For example, when service failures occur, implementing clear response protocols that include immediate resolution steps, appropriate compensation, and acknowledgment of responsibility would demonstrate reliability and maintain elderly passengers' trust despite occasional service issues.

Perceived service quality significantly influences trust formation among elderly passengers. Therefore, to improve service quality, providers should prioritize the three strongest indicators identified: reliability, convenience, and staff interactions. Reliability should be enhanced through better timetable adherence, reduced journey times, and enhanced service frequency. Convenience should be improved via accessible facilities and intuitive wayfinding systems tailored to elderly needs. Staff interactions require targeted training programs emphasizing respectful communication and specialized assistance for elderly passengers with mobility limitations. In the post-pandemic context, health and safety concerns remain important; therefore, maintaining enhanced cleaning protocols, improving ventilation systems, and implementing effective crowd management would address these concerns among vulnerable elderly passengers.

To strengthen commitment, the second most important loyalty factor, providers should develop recognition programs offering loyalty incentives and priority services to long-term elderly users. Public transportation should be positioned as an essential community service through collaboration with elderly associations and hosting community events. Communication campaigns highlighting environmental and societal benefits may resonate with elderly passengers' desire to contribute positively. Involving elderly citizens in transportation planning would foster ownership and psychological bonds that reinforce loyalty.

For enhancing perceived value, the third strongest predictor, providers should develop pricing schemes demonstrating clear value through discounted fares or integrated mobility packages. Non-monetary value improvements should include reduced waiting times, priority boarding, and comfortable waiting areas, particularly valuable to elderly passengers. Enhanced first/last mile connectivity and accessibility to essential services would further strengthen value perceptions.

Thailand's rapidly aging demographic profile and low public transportation utilization among elderly citizens necessitate an integrated policy approach. Transportation authorities should develop a comprehensive strategy addressing elderly mobility needs as part of healthy aging and social participation. Coordination between transportation, healthcare, and urban planning agencies would ensure holistic approaches to mobility challenges. Regular monitoring of elderly passengers' perceptions would enable providers to address issues proactively. Innovative funding mechanisms are needed to sustain elderly-friendly transportation improvements while managing the economic challenges of serving an increasing proportion of discounted-fare passengers. By implementing these evidence-based recommendations focusing on trust, commitment, and perceived value, transportation authorities in Thailand can enhance elderly ridership, improve service experiences, and develop a more inclusive transportation system capable of supporting the country's rapidly aging population.

3.8 Limitations and future work

This study offers valuable insights into elderly passengers' loyalty to public transportation in Thailand, but several limitations should be acknowledged. While the sample included participants from both urban and rural areas across Thailand's five regions, the study did not specifically analyze urban-rural differences in loyalty formation pathways an important consideration given Thailand's significant urban-rural disparities in transportation infrastructure, service availability, and accessibility. Additionally, although this study focused on regional public transportation systems which share similar characteristics, it did not address policy implications specific to different regional contexts, which could provide valuable guidance for targeted service improvements and infrastructure development. Finally, while the model explained a significant but not complete portion of variance in loyalty, suggesting that future research should explore additional variables such as information technology adoption, environmental consciousness, and mobility-as-a-service concepts. Future work should address these limitations by conducting comparative urban-rural analyses, developing region-specific policy recommendations, and expanding the theoretical framework to capture emerging factors influencing elderly passengers' transportation choices in Thailand's rapidly evolving demographic and mobility landscape.

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Appendix 3.1 Questionnaire items of service quality variables

Item	Measures	No.	Questionnaire Items
EX1-PE1	Vehicle characteristic	1	Buses interiors are clean and usable
		2	Buses interiors have comfortable temperature
		3	Buses interiors have adequate lighting
		4	Buses interiors are free from disturbing noise and vibration
		5	Buses have adequate seating space and comfort
		6	Buses have convenient facilities (trash bins, power outlets, Wi-Fi)
		7	Overall, Bus is in good condition and feels safe
EX2-PE2	Bus stop characteristic	1	Bus stops are clean and usable
		2	Bus stops have weather protection
		3	Bus stops have adequate lighting
		4	Bus stops have adequate seating and waiting space
		5	Bus stops have convenient facilities (trash bins, power outlets, Wi-Fi)
		6	Overall, Bus stops are in good condition without damage
EX3-PE3	Accessibility	1	Easy access to bus stop via roads/sidewalks
		2	Multiple transport modes connect to bus stop
		3	Appropriate distance from home to bus stop
		4	Bus stop location is appropriate and accessible
		5	Appropriate distance between bus stops
		6	Bus routes comprehensively cover various areas

Note: EX represents the expectation of service quality, and PE represents the perception of service quality. Each item under both constructs was measured using a 7-point Likert scale, ranging from 1 (Strongly disagree) to 7 (Strongly agree).

Appendix 3.1 Questionnaire items of service quality variables (Continued)

Item	Measures	No.	Questionnaire Items
		1	Service is easy and convenient (payment, ticketing, reservations)
		2	Convenient connections with other transport modes
EX4-PE4	Convenience	3	Convenient boarding and alighting
		4	Adequate and convenient luggage storage
		5	Adequate service frequency
		1	Adequate travel information at bus stops
		2	Adequate travel information on buses
EX5-PE5	Information	3	Advance notification of schedule changes
		4	Information about connections with other public transport
		5	Complaint channels available for service quality
		1	Driver has safe driving behavior
		2	Driver/staff are ready for work (well-rested, sober)
		3	Driver/staff are attentive to passenger needs
EX6-PE6	Staff	4	Driver/staff are dedicated and willing to serve
		5	Driver/staff provide polite and friendly service
		6	Driver/staff have good attitudes toward elderly
		1	Safe travel (no accidents or breakdowns)
		2	Safe bus stop usage (no obstacles, non-slip surfaces)
		3	Personal and property safety during travel
EX7-PE7	Safety and security	4	Personal and property safety at bus stops
		5	Appropriate safety equipment provided
		6	Safety guidance and instructions provided

Note: EX represents the expectation of service quality, and PE represents the perception of service quality. Each item under both constructs was measured using a 7-point Likert scale, ranging from 1 (Strongly disagree) to 7 (Strongly agree).

Appendix 3.1 Questionnaire items of service quality variables (Continued)

Item	Measures	No.	Questionnaire Items
EX8-PE8	Reliability	1	Regular and consistent service
		2	Service follows schedule
		3	Punctual arrivals and departures
		4	Buses follow designated routes and stops
		5	Appropriate waiting times
		6	Appropriate travel times
		7	Legal speed limits observed
EX9-PE9	Affordability	1	Reasonable and affordable fares
		2	Good value for money
		3	Cheaper than other transport modes
		4	Discounted rates for weekly/monthly/annual passes
		5	Reasonable fare increases with better service
EX10-PE10	Facilities and support for the elderly	1	Clear visual and audio information on buses
		2	Special seating for elderly and wheelchair users on buses
		3	Handrails and stair rails on buses
		4	Assistance channels or call buttons on buses
		5	Ramps/lifts for wheelchair users on buses
		6	Low boarding steps
		7	Clear visual and audio information at bus stops
		8	Special seating for elderly and wheelchair users at bus stops
		9	Special parking spaces for elderly and wheelchair users at bus stops

Note: EX represents the expectation of service quality, and PE represents the perception of service quality. Each item under both constructs was measured using a 7-point Likert scale, ranging from 1 (Strongly disagree) to 7 (Strongly agree).

Appendix 3.1 Questionnaire items of service quality variables (Continued)

Item	Measures	No.	Questionnaire Items
EX11-PE11	Post-pandemic prevention	1	Good air circulation on buses and at bus stops
		2	Staff wear masks and gloves during outbreaks
		3	Staff provide disease prevention information
		4	Screening measures during outbreaks (registration, vaccination checks, temperature checks)
		5	Prevention measures during outbreaks (distancing, masks, barriers)
		6	Control measures during outbreaks (hand washing, cleaning procedures

Note: EX represents the expectation of service quality, and PE represents the perception of service quality. Each item under both constructs was measured using a 7-point Likert scale, ranging from 1 (Strongly disagree) to 7 (Strongly agree).

CHAPTER IV

A COMPARISON OF ELDERLY INTENTION TO USE SMART PUBLIC TRANSPORTATION BETWEEN URBAN AND RURAL AREAS IN THAILAND: AN INTEGRATED TAM–TPB MODEL

4.1 Abstract

This study examines elderly behavioral intention to use smart public transport systems across urban and rural Thailand through an integrated Technology Acceptance Model (TAM) and Theory of Planned Behavior (TPB) framework. Using stratified sampling, 1,189 elderly participants aged 60 years and above (631 urban, 558 rural) completed structured questionnaires measuring six constructs: perceived ease of use, perceived usefulness, attitude toward smart public transport, subjective norm, perceived behavioral control, and behavioral intention. Structural equation modeling and multigroup analysis were employed to test eight hypotheses and compare acceptance patterns between geographical contexts. Results demonstrate strong empirical support for all hypothesized relationships across both contexts. Rural elderly exhibited enhanced sensitivity to ease of use considerations, stronger social influence effects, and greater importance of perceived behavioral control. Urban elderly demonstrated superior ability to recognize technological benefits while maintaining more balanced factor influences. The measurement invariance testing confirmed construct equivalence across groups (ΔCFI = 0.005), supporting meaningful cross-group comparisons. Findings reveal that rural elderly require more intuitive interfaces and comprehensive social support systems, while urban elderly can accommodate more sophisticated technological features, informing context-specific implementation strategies for Thailand's smart public transport development.

4.2 Introduction

4.2.1 Research background

The global transition toward digitalized transportation systems presents unprecedented opportunities and challenges for aging societies worldwide. This transformation is particularly critical in developing countries like Thailand, where rapid technological advancement intersects with accelerating demographic change to create complex mobility challenges for elderly populations (Elassy et al., 2024; Zhou et al., 2020). As nations globally implement smart public transport initiatives to enhance efficiency, sustainability, and accessibility, understanding elderly users' acceptance of these technologies becomes essential for inclusive urban development (Ahn & Park, 2022; Porru et al., 2020).

Thailand exemplifies this demographic-technological convergence, with its population aging at an unprecedented rate. In 2023, approximately 19.97% of Thailand's population (13.2 million people) is aged 60 years or older, and projections indicate this proportion will exceed 20% by 2025, officially transitioning Thailand to a "complete-aged society" (Department of Older Persons, 2024). This demographic shift occurs alongside ambitious transportation modernization efforts, creating an urgent need to ensure that smart public transport systems are accessible and acceptable to elderly users across diverse geographical contexts (Champahom et al., 2024; Watcharamaisakul et al., 2025).

The concept of smart public transport encompasses integrated technological systems designed to optimize user experience through real-time information, digital payment methods, automated scheduling, and enhanced safety features (Elassy et al., 2024; Wang et al., 2021). These systems typically include GPS-based vehicle tracking, mobile applications for service access, electronic ticketing systems, real-time passenger information displays, and IoT-enabled infrastructure monitoring (Porru et al., 2020). While such technologies promise improved efficiency and user convenience, their implementation raises critical questions about digital accessibility for elderly populations who may face technological barriers (An, 2024; Zhou et al., 2020).

Research on elderly transportation behavior reveals complex relationships between age-related factors and technology acceptance. Physical limitations, cognitive changes, reduced confidence with digital interfaces, and limited prior technology exposure can significantly influence elderly individuals' willingness to adopt smart public transport services (Al-Rashid et al., 2021; Sun et al., 2020; Yu & Liu, 2024). Simultaneously, elderly often prioritize safety, reliability, and familiarity in transportation choices, factors that smart systems could potentially enhance through improved information provision and service predictability (Bond et al., 2017; Yan et al., 2022).

International experience demonstrates that successful smart public transport implementation requires careful consideration of user diversity and acceptance patterns. Studies from developed countries show that elderly users can successfully adopt smart public transport technologies when systems are designed with age-friendly interfaces and adequate support mechanisms (Guo et al., 2025; Mouratidis & Serrano, 2021). However, research in developing country contexts remains limited, particularly regarding how socioeconomic factors, infrastructure disparities, and cultural considerations influence elderly technology acceptance in transportation (Ganga et al., 2025; Wang et al., 2025).

4.2.2 Urban vs. rural smart public transport adoption

This demographic-technological context creates distinct challenges when examining urban versus rural transportation patterns. The disparity between urban and rural transportation contexts in Thailand creates distinct patterns of public transport adoption and behavioral intention, particularly among elderly populations. Urban areas typically benefit from more comprehensive public transport networks, higher service frequency, and greater integration of smart technologies, while rural areas often rely on limited, less frequent services with minimal technological integration (Bond et al., 2017; Porru et al., 2020; Schasché et al., 2023).

Research reveals that elderly individuals in urban settings generally have better access to public transport infrastructure and are more likely to encounter technology-enabled services in their daily lives. However, this exposure does not automatically translate to acceptance or usage intention. Zhang et al. (2018) have shown that elderly public transport usage is influenced by personal, attitudinal, household, social environment, and built environment factors, with significant differences between urban and rural contexts.

Rural elderly populations face unique challenges including longer distances to transport nodes, limited service coverage, and reduced exposure to digital technologies. Research in rural communities has identified that transportation barriers among older adults include service hours, service areas, trip destinations, and vehicle accessibility concerns (Yu & Liu, 2024). These geographical and infrastructural differences necessitate distinct approaches to understanding behavioral intention toward smart public transport adoption.

Studies examining demand-responsive transport services in rural areas have found that performance expectancy and attitudes toward public transport significantly impact behavioral intention to use these services (König & Grippenkoven, 2020; Schasché et al., 2023). Research has also shown that rural older adults value basic service features such as availability and affordability, while also appreciating technological features like real-time updates more than service providers typically expect (Yu et al., 2024).

The complexity of urban-rural differences in elderly technology acceptance requires comprehensive research frameworks that can capture the multifaceted nature of behavioral intention formation in diverse geographical contexts (Delgado-Viñas & Gómez-Moreno, 2022; Setthasuravich et al., 2024). As Thailand continues its transition toward becoming a digitally enhanced, age-friendly transportation system, understanding these contextual differences becomes crucial for effective policy implementation and service design (Champahom et al., 2024; Dangbut et al., 2024).

4.2.3 Theoretical integration

The Technology Acceptance Model (TAM), developed by Davis (1989), has emerged as one of the most influential frameworks for understanding technology adoption behavior. TAM identifies perceived usefulness and perceived ease of use as primary determinants of technology acceptance, with attitude serving as a mediating factor between these perceptions and behavioral intention. In the context of public transport, TAM has been extensively validated across various technological implementations, including autonomous buses, smart transit systems, and mobile transportation applications, demonstrating its robustness in explaining user acceptance of transportation technologies (Chen, 2019; Wang et al., 2021; Wu et al., 2021).

The Theory of Planned Behavior (TPB), proposed by Ajzen (1991), extends the Theory of Reasoned Action by incorporating perceived behavioral control as a predictor of behavioral intention alongside attitude and subjective norms. TPB has been widely applied in transportation research, particularly in understanding public transport usage intentions and mode choice behavior. Research has consistently shown that attitude, subjective norms, and perceived behavioral control significantly predict intentions to use public transport across diverse cultural and geographical contexts, with studies demonstrating TPB's effectiveness in explaining travel behavior in both developed and developing countries (Bandyopadhyaya & Bandyopadhyaya, 2022; Ng & Phung, 2021; Yan & Jin, 2023; Zhao & Gao, 2022).

Recent research has increasingly adopted integrated TAM-TPB approaches to capture both technological and behavioral aspects of public transport adoption, recognizing that technology acceptance involves complex interactions between system characteristics and user behavioral patterns. Studies have demonstrated that combined models provide superior explanatory power compared to individual frameworks, with integrated approaches showing substantially higher predictive capability for behavioral intention toward various transportation technologies (Matubatuba & De Meyer-Heydenrych, 2022; Moták et al., 2017; Saeidi et al., 2024; Sun et al., 2022). Research on autonomous electric buses and bus rapid transit systems has shown that combining TAM constructs (perceived usefulness, perceived ease of use) with TPB elements (attitude, subjective norms, perceived behavioral control) creates comprehensive frameworks that effectively predict adoption intentions across diverse user populations (Ganga et al., 2025; Matubatuba & De Meyer-Heydenrych, 2022).

The integration of these theoretical frameworks becomes particularly relevant when examining elderly populations, who may exhibit distinct technology acceptance patterns compared to younger users. Studies focusing on elderly technology adoption have found that traditional TAM constructs require enhancement through behavioral considerations, as older adults' adoption decisions are influenced by social support systems, confidence levels, and cultural factors captured by TPB components (Dangbut et al., 2024; Zhou et al., 2020). Research on elderly acceptance of transportation technology in developing countries has demonstrated that integrated TAM-TPB models provide more nuanced understanding of adoption mechanisms, particularly when examining geographical variations in technology acceptance patterns (Watcharamaisakul et al., 2025; Wisutwattanasak et al., 2025).

4.2.4 Research gap

While these theoretical frameworks provide valuable insights, several critical research gaps remain in their application to elderly populations in developing country contexts.

First, despite extensive research on general population acceptance of smart public transport technologies (Ahn & Park, 2022; Ganga et al., 2025; Wang et al., 2021), studies specifically focusing on elderly users remain limited. Existing elderly transportation research has primarily concentrated on conventional public transport systems (Al-Rashid et al., 2021; Zhang et al., 2018) or autonomous vehicles (Acheampong & Cugurullo, 2019; Zhang et al., 2019; Zhu et al., 2020), with minimal attention to integrated smart public transport technologies. Most studies examining urban-rural differences have not specifically addressed how technological acceptance varies between these contexts among elderly populations (Delgado-Viñas & Gómez-Moreno, 2022; Setthasuravich et al., 2024), particularly in developing countries where infrastructure and digital literacy disparities are pronounced.

Second, while integrated TAM-TPB models have been applied to various transportation contexts (Matubatuba & De Meyer-Heydenrych, 2022; Sun et al., 2022; Wang et al., 2025), their application to elderly users of smart public transport systems remains underexplored. Most studies have used either TAM or TPB independently (Bandyopadhyaya & Bandyopadhyaya, 2022; Shaaban & Maher, 2020; Wu et al., 2021), or when integrated models have been employed, they have focused on general populations rather than addressing elderly users' specific needs and constraints

(Matubatuba & De Meyer-Heydenrych, 2022; Moták et al., 2017; Saeidi et al., 2024; Sun et al., 2022).

Third, the majority of existing research has been conducted in developed countries and China (Guo et al., 2025; Mouratidis & Serrano, 2021; Wang et al., 2021; Wu et al., 2021), with limited studies in Southeast Asian contexts. Research in Thailand specifically examining elderly acceptance of smart public transport technologies is virtually nonexistent, despite the country's rapid aging and ongoing transportation infrastructure modernization (Dangbut et al., 2024; Watcharamaisakul et al., 2025).

4.2.5 Research objective and contributions

Addressing these identified gaps, the primary objective of this study is to examine and compare elderly behavioral intention to use smart public transport systems in urban and rural Thailand through an integrated TAM-TPB theoretical framework. Specifically, this research aims to:

1) To Investigate the applicability of integrated TAM-TPB model in predicting elderly behavioral intention toward smart public transport adoption in both urban and rural contexts, building upon previous research on technology acceptance in transportation (Herrenkind et al., 2019; Wu et al., 2021).

2) To Compare the relative importance of TAM and TPB constructs (perceived ease of use, perceived usefulness, attitude, subjective norm, and perceived behavioral control) in influencing elderly behavioral intention between urban and rural areas, extending the work of researchers who have examined urban-rural differences in transportation behavior (Chen, 2019; Schasché et al., 2023; Zhang et al., 2018).

3) To Provide evidence-based recommendations for policymakers and service providers to enhance smart public transport accessibility and adoption among elderly populations in different geographical contexts, supporting Thailand's transportation infrastructure development strategy (Dangbut et al., 2024; Ministry of Transport, 2020).

This study makes significant contributions across theoretical, practical, and methodological dimensions. Theoretically, the research extends integrated TAM-TPB models by examining their applicability to elderly users in smart public transport contexts and contributes to understanding how geographical factors moderate technology acceptance relationships for vulnerable populations (Section 4.3). The findings provide evidence-based insights for transportation policymakers in developing countries facing demographic transitions and offer specific guidance for designing age-friendly smart public transport systems across different geographical contexts (Section 4.6). Methodologically, the application of multigroup structural equation modeling provides a robust framework for comparing technology acceptance across geographical contexts, demonstrating how technology acceptance research can be adapted for specific demographic considerations in developing countries experiencing urbanization and population aging (Section 4.4 and Section 4.5).

4.3 Literature review and hypotheses

The theoretical foundations established through the Technology Acceptance Model and Theory of Planned Behavior provide the framework for understanding elderly behavioral intention toward smart public transport adoption. While TAM offers insights into how technological characteristics influence user acceptance, TPB contributes understanding of social and behavioral factors that shape adoption decisions. The integration of these theoretical perspectives enables comprehensive examination of the complex factors influencing elderly technology acceptance across diverse geographical contexts.

This section presents a comprehensive review of literature supporting the development of eight hypotheses examining the relationships between TAM and TPB constructs in predicting elderly behavioral intention to use smart public transport systems, as shown in Table 4.1.

Table 4.1 Summary of research hypotheses and relationship

Research	Theory Based on	Hypothesis and Relationship	Key Findings
Ganga et al. (2025), Herrenkind et al. (2019), (Sun et al., 2020), Wu et al. (2021), Zhou et al. (2020)	TAM	**H1:** Perceived ease of use ⟶(+) Perceived usefulness	• Driverless bus research shows ease of use enhances users' appreciation of system capabilities. • Autonomous electric bus studies confirm that when users find systems easy to operate, they better recognize practical benefits. • Gerontechnology research shows ease of use serves as gateway to appreciating technological value among elderly.
Ganga et al. (2025), Matubatuba and De Meyer-Heydenrych (2022), Mouratidis and Serrano (2021), Wisutwattanasak et al. (2025), Wu et al. (2021), Zhou et al. (2020)	TAM	**H2:** Perceived ease of use ⟶(+) Attitude toward smart public transport	• Autonomous bus research shows intuitive interfaces significantly shape user attitudes. • Bus rapid transit studies confirm user-friendly design enhances positive attitude formation. • Research on elderly users shows perceived ease of use significantly influences attitudes.
Wu et al. (2021), Sun et al. (2020), Yan et al. (2022),	TAM	**H3:** Perceived ease of use ⟶(+) Behavioral intention to use	• Autonomous bus research shows perceived ease of use significantly affects behavioral intention. • Continuance intention studies of autonomous buses confirm users prioritize effortless interaction. • Elderly research shows older adults reject complex systems regardless of benefits.
Dangbut et al. (2024), Ganga et al. (2025), Herrenkind et al. (2019), Saeidi et al. (2024), Sun et al. (2020), Wisutwattanasak et al. (2025)	TAM	**H4:** Perceived usefulness ⟶(+) Attitude toward smart public transport	• Autonomous electric bus research shows users develop positive attitudes when perceiving practical benefits like safety and efficiency. • Public bus studies during pandemic confirm perceived usefulness influences attitudes. • Research on elderly users shows perceived usefulness strongly influences attitudes.
Dangbut et al. (2024), Matubatuba and De Meyer-Heydenrych (2022), Sun et al. (2020), Wisutwattanasak et al. (2025), Wu et al. (2021)	TAM	**H5:** Perceived usefulness ⟶(+) Behavioral intentions to use	• Driverless bus research shows perceived usefulness serves as primary predictor of adoption intentions. • Bus rapid transit studies confirm perceived usefulness significantly predicts behavioral intentions. • Elderly users' research shows perceived usefulness as strongly influences behavioral intentions.

Note: TAM: Technology Acceptance Model, TPB: Theory of Planned Behavior, ⟶ regression on.

Table 4.1 Summary of research hypotheses and relationship (Continued)

Research	Theory Based on	Hypothesis and Relationship	Key Findings
Al-Rashid et al. (2021), Bandyopadhyaya and Bandyopadhyaya (2022), Champahom et al. (2024), Ganga et al. (2025), Ng and Phung (2021), Wisutwattanasak et al. (2025)	TPB	**H7:** Subjective norm ⟶(+) Behavioral intention to use	• Bus travel research shows family recommendations and social approval significantly affect users' intentions during pandemic. • In developing countries, studies confirm social norms impact intentions more than personal attitudes in collectivistic cultures. • Elderly users' research shows that social influence critically affects transportation choices and intention.
(Wu et al., 2021) (Matubatuba & De Meyer-Heydenrych, 2022), Wisutwattanasak et al. (2025), (Zhou et al., 2020)	TPB	**H8:** Perceived behavioral control ⟶(+) Behavioral intention to use	• Autonomous bus research shows users' confidence in their ability to use systems is primary determinant of adoption intentions. • Bus rapid transit studies confirm facilitating conditions and perceived control significantly predict behavioral intentions. • Research on elderly users shows confidence in ability to use systems as primary influence behavioral intention.

Note: TAM: Technology Acceptance Model, TPB: Theory of Planned Behavior, ⟶ regression on.

4.3.1 Technology acceptance model (TAM) relationships

4.3.1.1 Perceived ease of use effects

The Technology Acceptance Model establishes three fundamental relationships involving perceived ease of use. First, perceived ease of use positively influences perceived usefulness, as technologies that are easier to operate are more likely to be recognized for their practical benefits (Davis, 1989). This association is consistently observed in research on smart public transport, where studies on autonomous buses highlight that intuitive interfaces and simple operational features enhance users' perceptions of system utility (Ganga et al., 2025; Herrenkind et al., 2019; Sun et al., 2022; Wu et al., 2021). Among elderly populations, this relationship becomes especially important, as ease of use often facilitates the recognition of technological value in gerontechnology (Zhou et al., 2020). Research on elderly acceptance of transport technology confirms that user-friendly systems enhance benefit recognition among aging populations (Dangbut et al., 2024; Sun et al., 2020).

Second, perceived ease of use directly influences users' attitudes toward technology, with systems requiring minimal effort fostering more favorable evaluations (Davis, 1989). Autonomous bus research indicates that passengers develop more positive attitudes when systems feature user-friendly interfaces (Mouratidis & Serrano, 2021). Research on autonomous buses and BRT systems confirms that user-friendly interfaces significantly enhance attitude formation (Ganga et al., 2025; Matubatuba & De Meyer-Heydenrych, 2022; Wu et al., 2021). This relationship is especially salient among elderly users, who are particularly sensitive to usability issues; ease of use plays a critical role in shaping their technology acceptance (Zhou et al., 2020). Studies in the elderly context further demonstrate that minimal effort requirements promote positive attitudes toward transport technology (Dangbut et al., 2024; Sun et al., 2020; Wisutwattanasak et al., 2025).

Third, perceived ease of use can directly affect behavioral intention, particularly for populations prioritizing simplicity and accessibility (Davis, 1989; Venkatesh & Davis, 2000). Studies on driverless and autonomous buses indicate that passengers often make primary decisions based on perceived simplicity (Sun et al., 2022; Wu et al., 2021). Continuance intention research confirms that users prioritize effortless interaction (Yan et al., 2022). Therefore:

H1: Perceived ease of use positively affects perceived usefulness.

H2: Perceived ease of use positively affects attitude toward smart public transport.

H3: Perceived ease of use positively affects behavioral intention to use.

4.3.1.2 Perceived usefulness effects

Perceived usefulness serves as a critical determinant of both attitude and behavioral intention within TAM (Davis, 1989). Empirical studies consistently demonstrate that users form more favorable attitudes toward technologies they perceive as beneficial in achieving their goals. In the context of autonomous electric buses, practical advantages such as enhanced safety and environmental sustainability have been shown to significantly strengthen user attitudes (Ganga et al., 2025; Herrenkind et al., 2019). Similarly, research on public transportation during the COVID-19 pandemic confirms that perceived usefulness positively influences attitudes toward bus services (Saeidi et al., 2024). Among elderly populations, this factor plays an especially important role; technologies that meet age-specific needs tend to generate stronger positive attitudes (Zhou et al., 2020). Evidence from studies on elderly users further supports this relationship, indicating that perceived usefulness plays a significant role in shaping attitudes toward transportation technologies (Dangbut et al., 2024; Sun et al., 2020; Wisutwattanasak et al., 2025).

Perceived usefulness also directly predicts behavioral intention, often emerging as the strongest predictor in technology acceptance models (Davis, 1989; Venkatesh & Davis, 2000). Perceived usefulness also directly predicts behavioral intention, often emerging as the strongest predictor in bus technology acceptance models. Autonomous bus research shows that perceived usefulness serves as the primary predictor of adoption intentions (Wu et al., 2021). Bus rapid transit studies demonstrate that perceived usefulness significantly predicts behavioral intentions among potential adopters (Matubatuba & De Meyer-Heydenrych, 2022). For elderly populations, research indicates that perceived usefulness represents the strongest predictor of adoption intention (Sun et al., 2020). Studies on elderly acceptance of transportation technology indicate that perceived usefulness is a key determinant of behavioral intention (Dangbut et al., 2024; Sun et al., 2020; Wisutwattanasak et al., 2025). Therefore:

H4: Perceived usefulness positively affects attitude toward smart public transport.

H5: Perceived usefulness positively affects behavioral intention to use.

4.3.2 Theory of planned behavior (TPB) relationships

4.3.2.1 Attitude toward behavior

The Theory of Planned Behavior establishes attitude as a direct predictor of behavioral intention, suggesting that favorable attitudes toward a behavior increase intention to perform that behavior (Ajzen, 1991). Research consistently shows that positive attitudes toward bus systems are associated with a greater likelihood of adoption. Studies on autonomous buses confirm a strong relationship between attitude and behavioral intention, indicating that user experiences which foster favorable attitudes are closely linked to future usage intentions and serve as significant predictors of long-term usage decisions (Mouratidis & Serrano, 2021; Yan et al., 2022). Similarly, studies on bus rapid transit systems indicate that attitudes shaped by the recognition of practical benefits have a direct impact on intention to adopt the service (Matubatuba & De Meyer-Heydenrych, 2022). Among elderly populations, transportation behavior studies show that positive attitudes formed through benefit–risk evaluation significantly predict usage intentions (Al-Rashid et al., 2021; Yan & Jin, 2023). Additional research on transportation technology adoption among older adults demonstrates that favorable attitudes, particularly those based on usefulness and ease of use, strongly influence behavioral intention (Dangbut et al., 2024; Sun et al., 2020; Watcharamaisakul et al., 2025; Wisutwattanasak et al., 2025). Therefore:

H6: Attitude toward smart public transport positively affects behavioral intention to use.

4.3.2.2 Subjective norm

Subjective norm represents perceived social pressure to perform a behavior and directly influences behavioral intention (Ajzen, 1991). In developing countries, public transportation research confirms that social norms impact intentions more than personal attitudes, particularly in collectivistic cultures (Bandyopadhyaya & Bandyopadhyaya, 2022; Ganga et al., 2025; Ng & Phung, 2021). Among elderly users, studies show that family recommendations and peer approval significantly shape intentions to use public transport services. During pandemic conditions, subjective norm has been found to exert a particularly strong influence on elderly users' behavioral intentions (Al-Rashid et al., 2021; Yan & Jin, 2023). Research on Thailand's high-speed rail adoption among elderly passengers further supports this, demonstrating that social approval and family influence play a decisive role in adoption decisions, often exerting greater influence than individual preferences in collectivist societies (Champahom et al., 2024; Dangbut et al., 2024; Watcharamaisakul et al., 2025; Wisutwattanasak et al., 2025). Therefore:

H7: Subjective norm positively affects behavioral intention to use.

4.3.2.3 Perceived behavioral control

Perceived behavioral control reflects individuals' perceived ease or difficulty of performing a behavior and directly predicts behavioral intention (Ajzen, 1991). Empirical evidence from autonomous bus studies indicates that perceived control significantly shapes usage intentions, with higher confidence levels directly enhancing users' willingness to engage with emerging technologies (Wu et al., 2021). Similarly, findings from bus rapid transit research reveal that perceived behavioral control is a significant predictor of system adoption (Matubatuba & De Meyer-Heydenrych, 2022). In the context of gerontechnology, studies show that elderly users' confidence in their ability to operate technologies serves as a primary determinant of adoption intentions (Zhou et al., 2020). Studies on elderly travel behavior during pandemic conditions further confirm that perceived behavioral control significantly influences public transport intentions (Al-Rashid et al., 2021; Yan & Jin, 2023). In Thailand, studies on high-speed rail use among elderly passengers highlight that confidence in system operation is essential for adoption. In such contexts, perceived control can act as either a facilitator or a barrier to technology acceptance, depending on the individual's level of self-efficacy (Champahom et al., 2024; Dangbut et al., 2024; Watcharamaisakul et al., 2025). Therefore:

H8: Perceived behavioral control positively affects behavioral intention to use.

4.3.3 Integrated TAM-TPB framework and research variables

Based on the literature review and hypotheses development presented above, this study proposes an integrated conceptual framework that combines the Technology Acceptance Model and Theory of Planned Behavior to examine elderly behavioral intention toward smart public transport usage. The complete integrated TAM-TPB model with all constructs, observed variables, and hypothesized relationships is illustrated in Figure 4.1.

The proposed model integrates five antecedent constructs (perceived ease of use, perceived usefulness, attitude toward smart public transport, subjective norm, and perceived behavioral control) with behavioral intention as the dependent variable, establishing eight hypothesized relationships that capture both technological and behavioral influences on elderly adoption decisions. The integrated model comprises three categories of variables with specific measurement structures:

1) Exogenous Variables (2 latent constructs, 8 observed variables): Perceived ease of use (PEOU1, PEOU2, PEOU3, PEOU4, PEOU5) and perceived

usefulness (PU1, PU2, PU3) serve as foundational technological predictors that initiate the acceptance process.

2) Endogenous Variables (4 latent constructs, 14 observed variables): Perceived usefulness functions with dual roles as described above. Attitude toward smart public transport (ATT1, ATT2, ATT3, ATT4) mediates technological influences on intention. Subjective norm (SN1, SN2, SN3) captures social pressure effects. Perceived behavioral control (PBC1, PBC2, PBC3, PBC4) reflects perceived ease of performance. Behavioral intention to use (BI1, BI2, BI3) serves as the ultimate dependent variable.

3) Mediating Variables: Perceived usefulness mediates the relationship between perceived ease of use and both attitude and behavioral intention. Attitude toward smart public transport mediates the relationships between both technological constructs and behavioral intention, creating pathways through which technological perceptions influence elderly users' adoption intentions across urban and rural contexts.

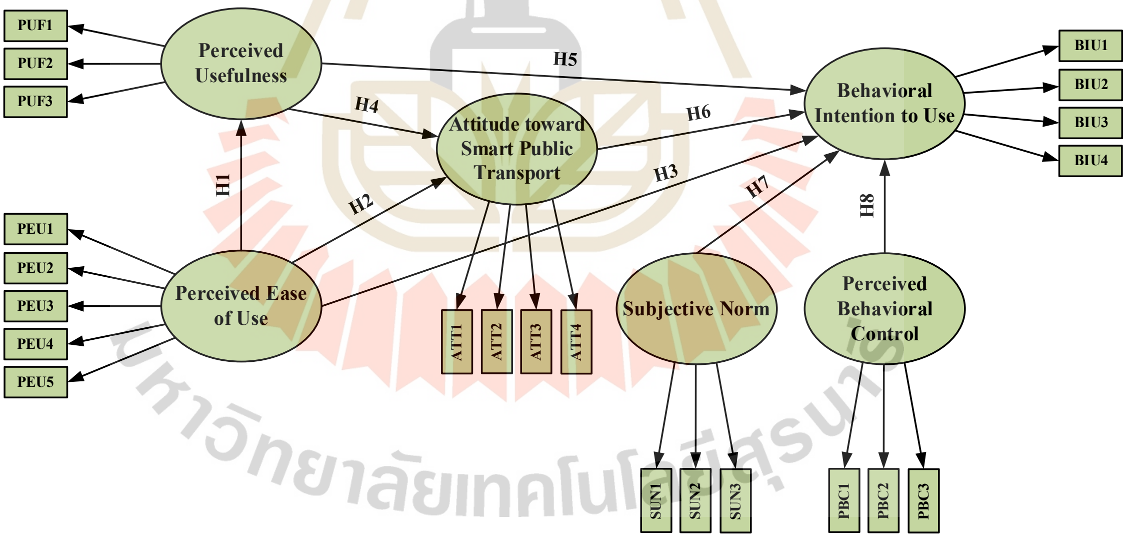

Figure 4.1 Conceptual frameworks and hypotheses

4.4 Materials and methods

4.4.1 Questionnaire development

This study employed a structured questionnaire based on the integrated TAM-TPB framework to measure elderly behavioral intention toward smart public transport usage. The questionnaire comprised six main constructs with a total of 21 observed variables measured using a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree) based on its optimal balance between measurement precision and respondent usability, providing superior discrimination capability over 5-point scales while avoiding the cognitive burden of 9-point scales that can overwhelm elderly respondents (Joshi et al., 2015).

Based on the theoretical foundations established in Table 4.1. and the comprehensive literature review of smart public transportation and elderly technology acceptance studies, the questionnaire development was grounded in the integrated TAM-TPB framework. The measurement items detailed in Table A4.1. were specifically designed to capture constructs validated across previous research on autonomous buses, bus rapid transit systems, and elderly transportation behavior.

Perceived ease of use was measured through five items (PEOU1-PEOU5) assessing elderly users' perceptions of effort required for smart public transport usage, including learning ease, information accessibility, system responsiveness, first-time user friendliness, and mode switching convenience. Perceived usefulness comprised three items (PU1-PU3) evaluating elderly users' beliefs about smart public transport's ability to facilitate travel convenience, reduce travel time, and enable personal activities during travel.

Attitude toward smart public transport was captured through four items (ATT1-ATT4) measuring elderly users' evaluative judgments regarding smart public transport as a good choice, important and beneficial option, worthwhile investment, and overall positive assessment. Subjective norm was assessed via three items (SUN1-SUN3) examining perceived social pressure from close relationships, including recommendations from people close to them, influence from friends' usage, and impact of loved ones' adoption behaviors.

Perceived behavioral control utilized four items (PBC1-PBC4) measuring elderly users' confidence in their ability to use smart public transport, encompassing prior public transport experience, sufficient knowledge and ability, confidence with guidance, and overall system control perceptions. Behavioral intention was evaluated through four items (BIU1-BIU4) assessing elderly users' expectations, plans, willingness to use smart public transport when available, and likelihood of recommending the system to others.

The questionnaire underwent translation and back-translation procedures from English to Thai to ensure linguistic equivalence (Brislin, 1970). Content validity was assessed through expert review using Item-Objective Congruence (IOC) analysis with five experts in transportation behavior and technology acceptance (Turner & Carlson, 2003). Items with IOC values below 0.5 were revised or eliminated (Rovinelli & Hambleton, 1976). The complete questionnaire items with their statistical properties, including means, standard deviations, skewness, kurtosis, and Cronbach's alpha values, are presented in Appendix 4.1.

4.4.2 Data collection

Data collection employed a stratified sampling approach targeting elderly participants aged 60 years and above who had previous experience using regional public transportation services across Thailand. The sampling framework captured representative perspectives from both urban and rural contexts across the country's four major geographical regions: Northern, Southern, Central, and Northeastern Thailand. Provincial selection criteria prioritized locations with established public transportation infrastructure serving both urban and rural populations, enabling meaningful comparison of elderly behavioral intention across varying levels of transportation service availability and technological integration.

The minimum required sample size was determined following established guidelines for structural equation modeling (SEM), which recommend a minimum of 10-15 observations per estimated parameter (Hair et al., 2019; Kline, 2015). Given the integrated TAM-TPB model's complexity with 21 observed variables and multiple structural paths, the minimum sample size requirement was calculated at approximately 315-420 participants. To ensure adequate statistical power for multigroup analysis comparing urban and rural contexts, the target sample was increased to accommodate potential response variability and enable robust cross-group comparisons.

Face-to-face interviews were conducted by trained research assistants to accommodate elderly participants' potential limitations with technology-related terminology and concepts. Research assistants provided standardized explanations about smart public transport concepts, including GPS-based vehicle tracking, mobile applications for service access, electronic ticketing systems, and real-time passenger information displays, before questionnaire administration. The data collection process adhered to ethical guidelines for research involving elderly participants, including comprehensive informed consent procedures and voluntary participation principles.

The data collection process yielded 1,189 valid responses, comprising 631 participants from urban areas (53.1%) and 558 participants from rural areas (46.9%). This sample size substantially exceeded the minimum SEM requirements, providing adequate statistical power for both individual group analyses and multigroup invariance testing. Urban participants were recruited from metropolitan areas and major provincial cities with established public transport networks, while rural participants were recruited from village communities and smaller municipalities served by regional bus services and other forms of rural public transportation. All participants met the inclusion criteria of being aged 60 years or above and having previous experience using public transportation services, ensuring sufficient familiarity with conventional public transport systems to evaluate potential smart technology enhancements meaningfully.

Demographic characteristics of the participants, including gender, marital status, age distribution, education level, occupation, and trip purposes, are presented in Table 4.2. The sample demographics show appropriate representation across different socioeconomic backgrounds and age groups within the elderly population, enabling comprehensive analysis of smart public transport acceptance patterns.

Table 4.2 Demographic data

Characteristics	Category	Urban area (n = 631)		Rural area (n = 558)	
		Frequency	Percentage	Frequency	Percentage
Gender	Male	307	48.7%	266	47.7%
	Female	324	51.3%	292	52.3%
Status	Single	63	10.0%	36	6.5%
	Married	409	64.8%	385	69.0%
	Divorced/Separated	159	25.2%	137	24.5%
Age	60–64 years old	265	42.0%	249	44.6%
	65–69 years old	216	34.2%	180	32.3%
	70–74 years old	102	16.2%	82	14.7%
	75–79 years old	30	4.8%	33	5.9%
	≥ 80 years old	18	2.8%	14	2.5%
Education	Below bachelor's degree	450	71.3%	489	87.6%
	Bachelor's degree	113	17.9%	45	8.1%
	Higher bachelor's degree	68	10.8%	24	4.3%
Occupation	Retired	137	21.7%	120	21.5%
	Government employee	24	3.8%	17	3.1%
	Private employee	51	8.1%	24	4.3%
	Business owners	158	25.1%	102	18.3%
	Agriculturist	62	9.8%	178	31.9%
	General laborer	188	29.8%	104	18.6%
	Other	11	1.7%	13	2.3%
Trip Purpose	Work	68	10.8%	43	7.7%
	Leisure/Travel	167	26.5%	123	22.1%
	Shopping	166	26.3%	153	27.4%
	Social activities	101	16.0%	46	8.2%
	Hospital/Medical appointment	103	16.3%	171	30.7%
	Other	26	4.1%	22	3.9%

Note: Sample size (N = 1,189).

4.4.3 Data preparation

Data cleaning and validation processes were conducted to ensure data quality and appropriateness for multivariate analysis. Missing data patterns were examined and addressed using listwise deletion for cases with incomplete responses, ensuring that only complete questionnaires were retained for analysis (Hair et al., 2019).

Normality assessment was performed through examination of skewness and kurtosis values for all observed variables, with acceptable ranges established as skewness < |2.0| and kurtosis < |7.0| to support maximum likelihood estimation procedures (West et al., 1995). Outlier detection was conducted using Mahalanobis distance calculations, with extreme cases identified and evaluated for potential exclusion based on statistical and theoretical considerations (Kline, 2015).

Group preparation involved categorizing participants into urban and rural subsamples based on their residential location characteristics, enabling subsequent multigroup analysis. The final dataset comprised 1,189 valid responses (631 urban, 558 rural) that met all inclusion criteria and data quality standards, providing adequate sample sizes for robust structural equation modeling procedures across both geographical contexts.

4.4.4 Data analysis

The data analysis process followed a research methodological framework, as illustrated in Figure 4.2, combining data preparation, measurement model assessment, and structural model evaluation using a multigroup analysis framework. The analysis was conducted using Mplus version 7.2 for structural equation modeling (SEM) procedures. This comprehensive analytical approach enabled robust examination of the integrated TAM-TPB model's validity and the comparison of elderly behavioral intention patterns across urban and rural contexts.

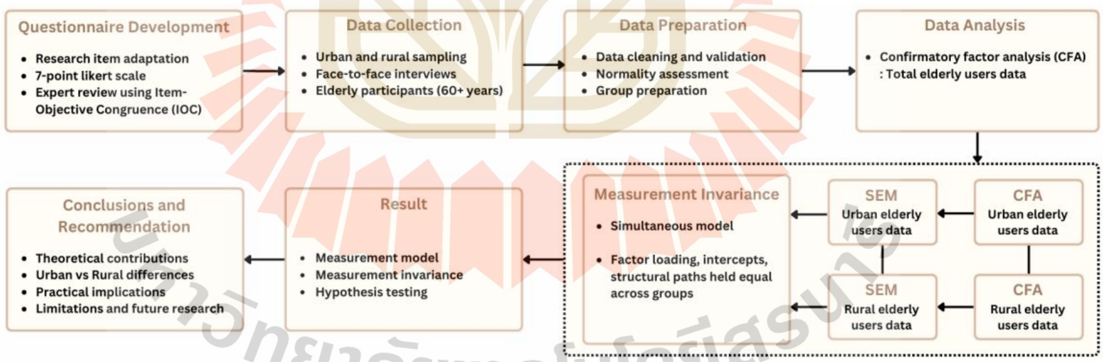

Figure 4.2 Research methodological framework

4.4.4.1 Confirmatory factor analysis (CFA)

Confirmatory Factor Analysis was conducted to evaluate the measurement model's validity and reliability before proceeding to structural model testing (Hair et al., 2019). The CFA examined the relationships between observed variables and their corresponding latent constructs across both urban and rural samples. The measurement model can be expressed as:

$$y = \Lambda\xi + \epsilon \quad (1)$$

where y represents the vector of observed variables, Λ is the matrix of factor loadings, ξ represents the vector of latent variables, and ϵ is the measurement error vector.

Model fit assessment utilized multiple indices including chi-square statistics (χ^2), degrees of freedom (df), comparative fit index (CFI), Tucker-Lewis index (Zhou et al.), standardized root mean square residual (SRMR), and root mean square error of approximation (RMSEA) with 90% confidence intervals (Hu & Bentler, 1999; Kline, 2015). The measurement model evaluation examined factor loadings (λ), t-values for statistical significance, squared multiple correlations (R^2), composite reliability (CR), and average variance extracted (AVE) for each construct (Fornell & Larcker, 1981). Acceptable thresholds were established as factor loadings ≥ 0.50, CR ≥ 0.70, and AVE ≥ 0.50, with all factor loadings required to achieve statistical significance at $p < 0.001$ (Hair et al., 2019).

4.4.4.2 Structural equation modeling (SEM)

Following satisfactory measurement model validation, structural equation modeling was employed to test the hypothesized relationships within the integrated TAM-TPB framework (Hair et al., 2019). The structural model examined eight hypothesized paths connecting perceived ease of use, perceived usefulness, attitude toward smart public transport, subjective norm, perceived behavioral control, and behavioral intention to use smart public transport. The structural model is represented by:

$$\eta = B\eta + \Gamma\xi + \zeta \quad (2)$$

where η represents the vector of endogenous latent variables, B is the matrix of coefficients relating endogenous variables to each other, Γ is the matrix of coefficients relating exogenous to endogenous variables, ξ represents the vector of exogenous latent variables, and ζ is the structural error vector.

Maximum likelihood estimation was utilized for parameter estimation, with bootstrap procedures applied to enhance robustness of standard error estimates (Hair et al., 2019). Model fit evaluation criteria followed established guidelines: CFI and TLI ≥ 0.90 for acceptable fit, SRMR ≤ 0.08, RMSEA ≤ 0.08 for good fit, and $\chi^2/df \leq 5.0$ for acceptable fit (Hu & Bentler, 1999; Steiger, 2007). Hypothesis testing examined standardized path coefficients (β), t-values, and statistical significance levels to determine support for the proposed relationships.

4.4.4.3 Measurement invariance

Measurement invariance testing was conducted to ensure that the integrated TAM-TPB model functioned equivalently across urban and rural groups, enabling meaningful comparison of structural relationships (Putnick & Bornstein, 2016; Sass & Schmitt, 2013). The invariance testing procedure followed a hierarchical approach examining configural invariance (equal form), metric invariance (equal factor loadings), and scalar invariance (equal intercepts).

The invariance assessment utilized chi-square difference tests and comparative fit index differences as primary evaluation criteria:

$$\Delta\chi^2 = \chi^2_{constrained} - \chi^2_{unconstrained} \quad (3)$$

$$\Delta CFI = CFI_{unconstrained} - CFI_{constrained} \quad (4)$$

Acceptable invariance was indicated by $\Delta CFI \leq 0.01$ and non-significant chi-square difference tests, or when practical significance criteria suggested minimal deterioration in model fit (Chen, 2007; Cheung & Rensvold, 2002). Four sequential models were evaluated: individual urban and rural models, simultaneous configural model, and constrained model with factor loadings, intercepts, and structural paths held equal across groups.

4.5 Results

4.5.1 Descriptive statistics

The descriptive statistics for all measurement items are presented in Appendix 4.1, revealing generally positive attitudes toward smart public transport adoption among elderly participants in both geographical settings, with mean scores ranging from 5.701 to 6.225 on the 7-point Likert scale. Urban participants demonstrated slightly higher mean scores across most constructs compared to their rural counterparts, with perceived ease of use means ranging from 5.911 to 6.076 (urban) versus 5.701 to 5.846 (rural), and perceived usefulness showing urban means of 5.854-5.918 compared to rural means of 5.762-5.835. Subjective norm measures revealed the highest mean scores among all constructs, with urban participants scoring between 6.038 and 6.087, and rural participants scoring between 5.842 and 5.862. Standard deviation values remained relatively consistent across groups (0.828-1.162), with skewness and kurtosis values generally falling within acceptable ranges for normal distribution assumptions, supporting the appropriateness of maximum likelihood estimation procedures for subsequent SEM analyses.

4.5.2 Measurement invariance

The measurement invariance testing results presented in Table 4.3 demonstrate the equivalence of the integrated TAM-TPB model across urban and rural groups, with individual group models achieving acceptable fit indices (urban: χ^2 = 655.170, df = 171, CFI = 0.941, TLI = 0.921, RMSEA = 0.067; rural: χ^2 = 474.862, df = 171, CFI = 0.958, TLI = 0.943, RMSEA = 0.056). The simultaneous model (Model 3) examining configural invariance achieved satisfactory fit (χ^2 = 1225.786, df = 348, CFI = 0.943, TLI = 0.924, RMSEA = 0.065), indicating equivalent factor structure across groups, while the constrained model (Model 4) testing metric and scalar invariance resulted in χ^2 = 1345.478 (df = 386, CFI = 0.938, TLI = 0.925, RMSEA = 0.065). Although the chi-square difference test yielded $\Delta\chi^2$ = 119.692 (Δdf = 38, $p < 0.001$), the CFI difference criterion showed ΔCFI = 0.005, remaining well below the recommended threshold of 0.01 (Cheung & Rensvold, 2002), supporting partial invariance that enables meaningful comparison of structural relationships between urban and rural elderly populations.

Table 4.3 Model fit indices for invariance test

Description	χ^2	*df*	χ^2/df	CFI	TLI	SRMR	RMSEA (90% CI)	$\Delta\chi 2$	Δdf	*p*
Individual groups										
Model 1: Urban	655.170	171	3.831	0.941	0.921	0.055	0.067 (0.062-0.072)			
Model 2: Rural	474.862	171	2.777	0.958	0.943	0.050	0.056 (0.050-0.062)			
Measurement of invariance										
Model 3: Simultaneous model	1225.786	348	3.522	0.943	0.924	0.054	0.065 (0.061-0.069)			
Model 4: Factor loading, intercepts, structural paths held equal across groups	1345.478	386	3.486	0.938	0.925	0.075	0.065 (0.061-0.068)	119.69	38	< 0.001

4.5.3 Measurement model

The confirmatory factor analysis results presented in Table 4.4 demonstrate measurement model performance for both urban and rural samples, with all factor loadings exceeding the recommended threshold of 0.50 and ranging from 0.551 to 0.906 in urban areas and 0.672 to 0.923 in rural areas (Hair et al., 2019). Perceived ease of use achieved high reliability with composite reliability (CR) values of 0.886 (urban) and 0.902 (rural), and average variance extracted (AVE) values of 0.610 (urban) and 0.649 (rural), while perceived usefulness demonstrated acceptable reliability with CR values of 0.802 (urban) and 0.823 (rural), and AVE values of 0.575 (urban) and 0.607 (rural). Subjective norm demonstrated the highest factor loadings across both samples, with urban loadings of 0.786-0.906 and rural loadings of 0.835-0.923, achieving excellent reliability with CR values of 0.891 (urban) and 0.904 (rural), and strong AVE values of 0.733 (urban) and 0.758 (rural). All constructs demonstrated adequate to excellent measurement properties, with statistical significance achieved for all factor loadings ($p < 0.001$), supporting the validity and reliability of the integrated TAM-TPB measurement model across both urban and rural contexts.

Table 4.4 Parameter estimation of measurement model

Constructs and Indicators	Urban area (n = 631)			Rural area (n = 558)		
	λ	t-value	R^2	λ	t-value	R^2
Perceived ease of use	(AVE = 0.610, CR = 0.886)			(AVE = 0.649, CR = 0.902)		
PEU1	0.706	31.549**	0.499	0.769	38.183**	0.592
PEU2	0.686	30.479**	0.471	0.716	31.159**	0.512
PEU3	0.831	55.302**	0.691	0.822	48.862**	0.676
PEU4	0.777	43.351**	0.604	0.833	52.377**	0.694
PEU5	0.887	71.129**	0.787	0.877	65.821**	0.769
Perceived usefulness	(AVE = 0.575, CR = 0.802)			(AVE = 0.607, CR = 0.823)		
PUF1	0.731	32.672**	0.535	0.744	31.274**	0.553
PUF2	0.813	44.939**	0.661	0.795	38.646**	0.632
PUF3	0.728	32.393**	0.530	0.798	38.378**	0.637
Attitude toward smart public transport	(AVE = 0.643, CR = 0.878)			(AVE = 0.637, CR = 0.875)		
ATT1	0.839	54.724**	0.703	0.829	45.252**	0.687
ATT2	0.856	58.906**	0.733	0.823	46.522**	0.677
ATT3	0.769	41.081**	0.591	0.782	38.931**	0.611
ATT4	0.737	32.884**	0.544	0.755	31.488**	0.570
Subjective norm	(AVE = 0.733, CR = 0.891)			(AVE = 0.758, CR = 0.904)		
SUN1	0.786	43.001**	0.618	0.851	56.296**	0.724
SUN2	0.906	73.426**	0.822	0.923	77.805**	0.851
SUN3	0.872	63.732**	0.760	0.835	52.992**	0.697
Perceived behavioral control	(AVE = 0.572, CR = 0.799)			(AVE = 0.610, CR = 0.824)		
PBC1	0.719	26.581**	0.517	0.802	21.587**	0.643
PBC2	0.844	40.038**	0.713	0.707	21.547**	0.500
PBC3	0.697	25.272**	0.485	0.829	22.959**	0.687
Behavioral intention to use	(AVE = 0.474, CR = 0.781)			(AVE = 0.551, CR = 0.831)		
BIU1	0.776	37.134**	0.602	0.779	36.038**	0.606
BIU2	0.706	29.486**	0.498	0.782	36.027**	0.612
BIU3	0.702	28.372**	0.493	0.732	29.526**	0.535
BIU4	0.551	17.693**	0.304	0.672	24.212**	0.451

Note: ** significant at $p < 0.001$; * significant at $p < 0.05$, λ denote standardized loading.

4.5.4 Hypothesis path

The structural equation modeling results presented in Table 4.5 demonstrate strong support for all eight hypothesized relationships within the integrated TAM-TPB framework across both urban and rural contexts. All hypothesized paths achieved statistical significance at $p < 0.001$, indicating robust relationships between the constructs in predicting elderly behavioral intention to use smart public transport.

Table 4.5 Results of hypothesis path testing

Hypothesis path	Urban area			Rural area		
	β	*t*-value	Result	β	*t*-value	Result
H1: Perceived ease of use ⟶ Perceived usefulness	0.530	15.465**	Supported	0.585	17.168**	Supported
H2: Perceived ease of use ⟶ Attitude toward smart public transport	0.152	16.234**	Supported	0.193	16.014**	Supported
H3: Perceived ease of use ⟶ Behavioral intention to use	0.143	15.608**	Supported	0.170	15.711**	Supported
H4: Perceived usefulness ⟶ Attitude toward smart public transport	0.847	31.435**	Supported	0.730	17.157**	Supported
H5: Perceived usefulness ⟶ Behavioral intention to use	0.177	16.271**	Supported	0.193	14.996**	Supported
H6: Attitude toward smart public transport ⟶ Behavioral intention to use	0.126	19.099**	Supported	0.117	16.195**	Supported
H7: Subjective norm ⟶ Behavioral intention to use	0.117	16.418**	Supported	0.137	16.263**	Supported
H8: Perceived behavioral control ⟶ Behavioral intention to use	0.126	14.664**	Supported	0.152	12.919**	Supported

Note: ⟶ regression on, ** significant at $p < 0.001$, β denote standardized estimate.

In urban areas, the structural model achieved acceptable fit indices (χ^2 = 655.170, df = 171, χ^2/df = 3.831, CFI = 0.941, TLI = 0.921, SRMR = 0.055, RMSEA = 0.067), demonstrating adequate representation of the data (see Figure 4.3). Perceived ease of use significantly influenced perceived usefulness (β = 0.530, t = 15.465), attitude toward smart public transport (β = 0.152, t = 16.234), and behavioral intention (β = 0.143, t = 15.608), providing strong support for hypotheses H1, H2, and H3. Perceived usefulness demonstrated the strongest effect on attitude toward smart public transport (β = 0.847, t = 31.435) and showed significant positive impact on behavioral intention (β = 0.177, t = 16.271), confirming hypotheses H4 and H5. The Theory of Planned Behavior components exhibited consistent significance, with attitude toward smart public transport positively influencing behavioral intention (β = 0.126, t = 19.099), subjective norm demonstrating moderate impact (β = 0.117, t = 16.418), and perceived behavioral control showing equivalent effects (β = 0.126, t = 14.664), supporting hypotheses H6, H7, and H8 respectively.

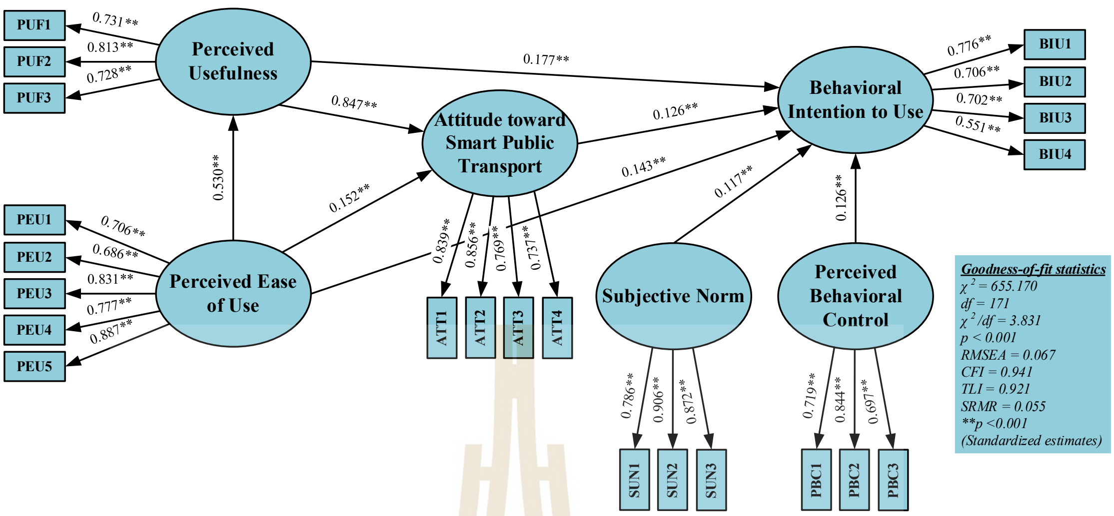

Figure 4.3 Structural equation modeling for smart public transport adoption intention in urban areas

Rural areas demonstrated superior model fit (χ^2 = 474.862, df = 171, χ^2/df = 2.777, CFI = 0.958, TLI = 0.943, SRMR = 0.050, RMSEA = 0.056), indicating excellent representation of the rural elderly population's behavioral patterns (see Figure 4.4). The rural model exhibited similar patterns with notable variations in effect sizes compared to urban areas. Perceived ease of use showed stronger influence on perceived usefulness (β = 0.585, t = 17.168), attitude (β = 0.193, t = 16.014), and behavioral intention (β = 0.170, t = 15.711), supporting hypotheses H1, H2, and H3 with greater effect magnitudes than urban contexts. Perceived usefulness significantly affected attitude toward smart public transport (β = 0.730, t = 17.157) and behavioral intention (β = 0.193, t = 14.996), confirming hypotheses H4 and H5. The TPB constructs demonstrated consistent significance with attitude toward smart public transport (β = 0.117, t = 16.195), subjective norm (β = 0.137, t = 16.263), and perceived behavioral control (β = 0.152, t = 12.919) all positively influencing behavioral intention, providing comprehensive support for hypotheses H6, H7, and H8. Notably, rural elderly showed stronger effects for subjective norm and perceived behavioral control compared to their urban counterparts, suggesting greater importance of social influences and perceived control in rural smart public transport adoption decisions.

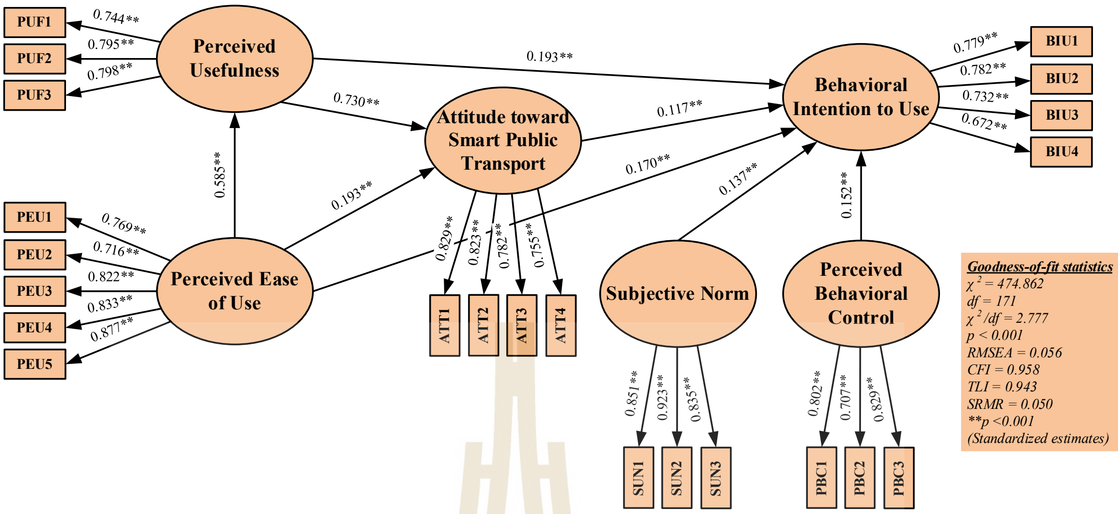

Figure 4.4 Structural equation modeling for smart public transport adoption intention in rural areas

4.6 Discussion

4.6.1 Discussing hypotheses

The comprehensive testing of all eight hypotheses within the integrated TAM-TPB framework demonstrates robust empirical support for the proposed theoretical model across both urban and rural contexts. The findings provide significant insights into the technological and behavioral determinants influencing elderly behavioral intention to use smart public transport systems in Thailand.

4.6.1.1 Technology acceptance model effects

Hypothesis 1 demonstrates that perceived ease of use positively affects perceived usefulness with strong support across both contexts, showing rural elderly enhanced sensitivity (rural: β = 0.585, t = 17.168; urban: β = 0.530, t = 15.465). This finding aligns with foundational TAM research (Davis, 1989) and extends these findings to elderly populations in developing country contexts. The stronger relationship observed in rural areas suggests that rural elderly may be more dependent on ease of use as a gateway to recognizing technological benefits, reflecting their typically limited exposure to digital technologies and supporting research on gerontechnology adoption that emphasizes ease of use as increasingly critical for older adults (Zhou et al., 2020).

Hypothesis 2 reveals that perceived ease of use positively affects attitude toward smart public transport with strong confirmation in both contexts, showing rural elderly enhanced effects (rural: β = 0.193, t = 16.014; urban: β = 0.152, t = 16.234). This finding reinforces the critical importance of user-friendly interface design for elderly populations and aligns with research on bus technology demonstrating that intuitive interfaces significantly influence elderly users' attitudes (Ganga et al., 2025; Matubatuba & De Meyer-Heydenrych, 2022; Wu et al., 2021). The stronger effects in rural contexts suggest that ease of use serves as a more critical attitude formation factor for rural elderly, who have less exposure to advanced technologies.

Hypothesis 3 confirms that perceived ease of use positively affects behavioral intention to use with strong support, displaying rural elderly enhanced effects (rural: β = 0.170, t = 15.711; urban: β = 0.143, t = 15.608). This finding is consistent with research on bus tecchnology behavior showing that older adults often make adoption decisions based primarily on perceived ease of use (Yan et al., 2022). The enhanced effects in rural contexts underscore the importance of simplicity and accessibility for rural elderly who may reject complex systems regardless of potential benefits.

Hypothesis 4 establishes that perceived usefulness positively affects attitude toward smart public transport with the strongest support across all hypotheses, revealing urban elderly achieving the highest effect magnitude (urban: β = 0.847, t = 31.435; rural: β = 0.730, t = 17.157). This finding confirms the fundamental importance of practical benefits in shaping elderly users' evaluations of smart public transport and aligns with research on autonomous electric buses (Ganga et al., 2025; Herrenkind et al., 2019) and elderly transportation technology adoption (Dangbut et al., 2024; Wisutwattanasak et al., 2025). The stronger effect in urban contexts suggests that urban elderly may be more adept at recognizing and valuing technological benefits, possibly due to greater familiarity with technology-enabled services.

Hypothesis 5 validates that perceived usefulness positively affects behavioral intention to use with strong confirmation, exhibiting relatively similar effects across contexts (rural: β = 0.193, t = 14.996; urban: β = 0.177, t = 16.271). This finding aligns with research on bus technology showing that perceived usefulness is a significant predictor of behavioral intentions among potential adopters (Matubatuba & De Meyer-Heydenrych, 2022; Wu et al., 2021). The practical implication emphasizes that demonstrating concrete benefits such as improved safety, reliability, and convenience will be crucial for encouraging elderly adoption.

4.6.1.2 Theory of planned behavior effects

Hypothesis 6 supports that attitude toward smart public transport positively affects behavioral intention to use with strong confirmation across both contexts, displaying similar effect magnitudes (urban: β = 0.126, t = 19.099; rural: β = 0.117, t = 16.195). This finding reinforces the established TPB relationship (Ajzen, 1991) and extends it to elderly smart public transport adoption, aligning with transportation research demonstrating strong attitude-intention relationships among elderly populations (Al-Rashid et al., 2021; Yan & Jin, 2023). The slightly stronger effect in urban areas may reflect urban elderly's greater familiarity with technology-enabled services, making attitude formation more predictive of behavioral intentions.

Hypothesis 7 confirms that subjective norm positively affects behavioral intention to use with strong support, indicating rural elderly enhanced effects (rural: β = 0.137, t = 16.263; urban: β = 0.117, t = 16.418). This finding is consistent with research in developing countries confirming that social norms impact intentions more than personal attitudes in collectivistic cultures (Bandyopadhyaya & Bandyopadhyaya, 2022; Ganga et al., 2025; Ng & Phung, 2021). The stronger effect in rural contexts reflects the collectivistic nature of rural Thai communities, where family recommendations and peer approval carry substantial weight in technology adoption decisions.

Hypothesis 8 verifies that perceived behavioral control positively affects behavioral intention to use with strong support, manifesting rural elderly achieving the highest effects (rural: β = 0.152, t = 12.919; urban: β = 0.126, t = 14.664). This finding highlights the critical importance of self-efficacy and confidence in elderly technology adoption, consistent with research showing that perceived control significantly influences elderly transportation behavior (Dangbut et al., 2024; Watcharamaisakul et al., 2025). The enhanced importance in rural contexts likely reflects limited technological infrastructure and reduced exposure to digital services, making confidence in one's ability to use new systems a more significant adoption barrier for rural elderly populations.

4.6.2 Urban and rural model comparison

The comparative analysis between urban and rural models reveals significant contextual differences in how elderly populations perceive and intend to adopt smart public transport technologies. Both models demonstrated strong empirical support for the integrated TAM-TPB framework, while exhibiting distinct patterns that reflect geographical and infrastructural disparities in Thailand's transportation landscape. The measurement invariance testing confirmed the equivalence of constructs across groups (ΔCFI = 0.005), supporting the validity of cross-group comparisons while revealing meaningful differences in structural relationships.

Urban elderly populations demonstrate a distinctive pattern characterized by stronger technological sophistication awareness and relatively balanced factor influences. Urban elderly showed moderate perceived ease of use effects on perceived usefulness (β = 0.530), attitude (β = 0.152), and behavioral intention (β = 0.143), suggesting sufficient technological exposure to appreciate smart systems even with moderate complexity levels. The urban model revealed the strongest perceived usefulness-attitude relationship (β = 0.847) across both contexts, indicating that urban elderly are particularly adept at recognizing and valuing practical benefits of smart public transport systems (Zhang et al., 2018). This pattern aligns with high-speed rail research demonstrating that urban elderly show greater capability in recognizing technological benefits and forming positive attitudes when systems address their mobility needs (Dangbut et al., 2024). Urban elderly demonstrated relatively moderate social influence effects (subjective norm: β = 0.117) and perceived behavioral control effects (β = 0.126), indicating that individual evaluation of technological benefits carries substantial weight in urban decision-making processes, supported by greater confidence in navigating new technologies through regular exposure to urban technological infrastructure (Setthasuravich et al., 2024; Wang et al., 2021).

Rural elderly populations exhibit markedly different acceptance patterns, characterized by heightened sensitivity to ease of use and stronger social and control influences. Rural elderly demonstrated significantly stronger perceived ease of use effects across all relationships: usefulness (β = 0.585), attitude (β = 0.193), and behavioral intention (β = 0.170), suggesting they require more intuitive and straightforward technological interfaces to appreciate system benefits due to limited exposure to advanced technologies (Delgado-Viñas & Gómez-Moreno, 2022; Setthasuravich et al., 2024). The rural model showed a strong but relatively lower perceived usefulness-attitude relationship (β = 0.730) compared to urban contexts, indicating that the pathway from recognizing benefits to forming positive attitudes is more dependent on ease of use considerations (Schasché et al., 2023; Yu et al., 2024). These findings are consistent with high-speed rail technology acceptance research, which found that rural elderly populations exhibit different acceptance mechanisms with greater emphasis on user-friendly interfaces and simplified operational procedures (Dangbut et al., 2024). Rural elderly demonstrated significantly stronger social influence effects (subjective norm: β = 0.137) and the strongest perceived behavioral control effects (β = 0.152), confirming the heightened importance of family and community approval alongside confidence barriers in rural decision-making processes, reflecting the collectivistic nature of rural Thai communities and limited technological infrastructure (Champahom et al., 2024; König & Grippenkoven, 2020).

4.6.3 Discussing implementation

The comparative analysis between urban and rural elderly populations reveals distinct implementation requirements that should guide smart public transport development strategies across Thailand's diverse geographical contexts.

Urban Implementation Strategy: Urban areas should leverage existing technological familiarity by emphasizing comprehensive benefit demonstration and sophisticated smart features. Given urban elderly's stronger ability to recognize technological benefits (perceived usefulness-attitude: β = 0.847), implementation should focus on advanced capabilities including real-time information systems, integrated mobile applications, and seamless payment integration. Progressive feature introduction with peer-to-peer learning programs can capitalize on moderate social influence effects while maintaining appropriate technology assistance centers at major transit hubs. This approach aligns with research by Zhou et al. (2020) and Wu et al. (2021), who found that urban elderly populations demonstrate superior capability in recognizing and valuing technological benefits, supporting the implementation of sophisticated smart features when properly demonstrated.

Rural Implementation Strategy: Rural areas require fundamentally different approaches prioritizing ease of use and community engagement. The significantly stronger perceived ease of use effects (β = 0.585) necessitate intuitive interface design and simplified operational procedures. Enhanced social influences (subjective norm: β = 0.137) require comprehensive community engagement through family-oriented training sessions, community leader endorsements, and peer ambassador programs. The strongest perceived behavioral control effects (β = 0.152) highlight the need for extensive hands-on training, on-site technical assistance, and dedicated support systems familiar with local contexts. These findings are strongly supported by Schasché et al. (2023) and König and Grippenkoven (2020), who emphasized that performance expectancy and facilitating conditions are critical for rural elderly adoption, while Bond et al. (2017) demonstrated the importance of partnerships and individualized outreach in rural transportation service provision.

Key Differentiation: While urban implementation can accommodate sophisticated features with individual-focused training, rural implementation must emphasize simplicity, reliability, and community-based support networks. Infrastructure development should prioritize consistent functionality over advanced features in rural areas, including offline capabilities and robust technical support. Both contexts require age-friendly design principles, but rural areas need more comprehensive social integration and confidence-building measures to ensure successful adoption among elderly populations. This differentiation is validated by Zhang et al. (2018), who identified significant urban-rural differences in elderly public transport usage patterns, and Yu et al. (2024), who found that rural older adults require more basic service features and comprehensive support systems compared to their urban counterparts.

These findings provide actionable guidance for policymakers and service providers to develop context-specific implementation strategies that address the unique needs and constraints of elderly populations across Thailand's urban-rural divide, supporting evidence from Champahom et al. (2024) regarding the enhanced importance of social influences in rural contexts and Al-Rashid et al. (2021) concerning psychosocial barriers affecting elderly public transport adoption.

4.7 Conclusion

This study successfully examined elderly behavioral intention to use smart public transport systems in Thailand through an integrated TAM-TPB theoretical framework, providing crucial insights into technology acceptance patterns across urban and rural contexts. The research comprehensively tested eight hypotheses and confirmed strong empirical support for all proposed relationships, demonstrating the robustness and applicability of the integrated model for understanding elderly technology adoption in developing country settings. The study involved 1,189 elderly participants (631 urban, 558 rural) aged 60 years and above, ensuring representative coverage across Thailand's diverse geographical landscape and providing adequate statistical power for rigorous multigroup analysis.

The findings reveal that both Technology Acceptance Model and Theory of Planned Behavior constructs significantly predict elderly behavioral intention to use smart public transport, with perceived usefulness emerging as the strongest predictor of attitude formation across both contexts (urban: β = 0.847; rural: β = 0.730). Perceived ease of use demonstrated consistent importance for elderly users, with particularly strong effects observed in rural contexts, highlighting the critical role of user-friendly interface design for successful technology adoption among older adults with limited technological exposure. The Theory of Planned Behavior components provided substantial additional explanatory power, with attitude toward smart public transport, subjective norm, and perceived behavioral control all significantly influencing behavioral intention across both geographical settings.

The comparative analysis revealed significant contextual differences between urban and rural elderly populations that have important implications for smart public transport implementation strategies. Rural elderly demonstrated consistently stronger perceived ease of use effects across all relationships, enhanced social influence from family and community networks (subjective norm: β = 0.137 vs. urban β = 0.117), and greater importance of perceived behavioral control (β = 0.152 vs. urban β = 0.126), reflecting their limited technological exposure and stronger reliance on social support systems. Urban elderly showed greater ability to recognize and value technological benefits, evidenced by the strongest perceived usefulness-attitude relationship, while demonstrating more balanced factors influences that suggest greater technological sophistication and individual decision-making autonomy.

The research contributes significantly to both theoretical understanding and practical application in several key areas. Theoretically, the study extends integrated TAM-TPB models by validating their applicability to elderly users in smart public transport contexts within a developing country framework, addressing critical gaps in age-inclusive technology acceptance research. The identification of differential acceptance mechanisms across urban and rural contexts provides valuable insights into how geographical and infrastructural factors moderate established technology acceptance relationships for vulnerable populations. Practically, the findings offer evidence-based guidance for transportation policymakers and service providers in Thailand and similar developing countries facing demographic transitions and infrastructure modernization challenges.

The measurement invariance testing confirmed the equivalence of constructs across urban and rural groups, supporting the reliability of cross-group comparisons while revealing meaningful structural differences that inform context-specific implementation strategies. The superior model fit achieved in rural contexts (CFI = 0.958, RMSEA = 0.056) compared to urban areas (CFI = 0.941, RMSEA = 0.067) suggests more homogeneous response patterns among rural elderly, possibly reflecting shared experiences of limited technology exposure and similar transportation challenges. These findings provide a solid foundation for developing targeted interventions that address the specific needs and constraints of elderly populations across diverse geographical contexts in Thailand's rapidly aging society.

4.8 Limitations and future research

While this study provides valuable insights into elderly behavioral intention toward smart public transport adoption in Thailand, several limitations should be acknowledged. The cross-sectional design captures behavioral intentions at a single point in time, preventing examination of how these intentions evolve or their relationship with actual adoption behavior. Future longitudinal studies should track elderly participants from initial exposure through repeated usage experiences, enabling examination of intention-behavior relationships and acceptance pattern stability over time (Guo et al., 2025; Yan et al., 2022).

The study's reliance on self-reported intentions rather than observed behavior represents a common limitation in technology acceptance research, as the intention-behavior gap has been well-documented across various contexts (Ganga et al., 2025; Wang et al., 2020). Future research should incorporate behavioral measures alongside intention assessments through pilot implementations of smart public transport systems that allow observation of actual elderly usage patterns. Such studies could employ mixed-methods approaches combining survey data with usage logs, observational studies, and in-depth interviews to provide comprehensive understanding of factors facilitating or hindering the transition from intention to actual adoption behavior.

The geographical scope, while covering Thailand's major regions, may limit generalizability to other developing countries with different cultural, economic, and infrastructure contexts. The specific characteristics of Thai society, including cultural values, family structures, and governmental policies toward aging populations, may influence the observed relationships (Champahom et al., 2024; Watcharamaisakul et al., 2025). Future research should examine similar phenomena across diverse developing country contexts, particularly in Southeast Asia and other regions experiencing rapid demographic transitions, to establish broader applicability of the integrated TAM-TPB framework.

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Appendix 4.1 Statistical summary

Item	Measures	Urban area (N = 631)				Rural area (N = 558)			
		Mean	SD	SK	KU	Mean	SD	SK	KU
	Perceived ease of use (Cronbach's α = 0.904)								
PEU1	Smart public transport is easy to learn.	6.076	1.045	-0.981	0.377	5.846	1.069	-0.601	-0.339
PEU2	Smart public transport provides easy access to service information.	6.013	1.008	-1.052	1.238	5.701	1.052	-0.519	-0.123
PEU3	Smart public transport responds easily to users.	5.911	1.105	-0.936	0.328	5.735	1.064	-0.550	-0.182
PEU4	Smart public transport is easy to use, even for first-time users.	6.048	1.013	-1.069	0.862	5.760	1.085	-0.603	-0.267
PEU5	It is easy to switch from other transportation modes to smart public transport.	5.927	1.105	-0.940	0.396	5.733	1.063	-0.451	-0.502
	Perceived usefulness (Cronbach's α = 0.807)								
PUF1	Smart public transport facilitates travel convenience.	5.886	0.920	-0.605	0.211	5.819	0.935	-0.678	0.763
PUF2	Smart public transport reduces travel time.	5.918	1.025	-0.846	0.255	5.835	0.958	-0.650	0.283
PUF3	Smart public transport allows me to do personal activities while traveling.	5.854	0.955	-0.648	0.537	5.762	0.951	-0.263	-0.718
	Attitude toward smart public transport (Cronbach's α = 0.865)								
ATT1	Smart public transport is a good choice	5.902	1.110	-0.805	-0.253	5.812	1.004	-0.578	-0.312
ATT2	Smart public transport is important and beneficial	5.862	1.012	-0.551	-0.554	5.724	1.015	-0.461	-0.374
ATT3	Smart public transport is worthwhile	5.981	1.045	-0.682	-0.560	5.797	1.006	-0.434	-0.624
ATT4	Overall, I have a positive attitude toward smart public transport.	5.983	0.955	-0.711	-0.114	5.765	1.006	-0.524	-0.264
	Subjective norm (Cronbach's α = 0.898)								
SUN1	People close to me will recommend using smart public transport.	6.038	1.151	-1.214	0.945	5.862	1.162	-0.955	0.566
SUN2	I would use smart public transport because my friends use it.	6.055	1.095	-1.363	1.761	5.842	1.137	-0.975	0.702
SUN3	I would use smart public transport because my loved ones use it.	6.087	1.006	-1.150	1.343	5.848	1.107	-0.877	0.390

Note: SD denote standard deviation, SK denote skewness, KU denote kurtosis.

Appendix 4.1 Statistical summary (Continued)

Item	Measures	Urban area (N = 631)				Rural area (N = 558)			
		Mean	SD	SK	KU	Mean	SD	SK	KU
	Perceived behavioral control (Cronbach's α = 0.805)								
PBC1	Having used public transport before, I can use smart public transport.	6.063	0.889	-0.737	0.086	5.932	0.906	-0.505	-0.222
PBC2	I am confident I have sufficient knowledge and ability to use smart public transport.	6.067	0.979	-0.817	-0.060	5.943	0.919	-0.527	-0.381
PBC3	I am confident I can use smart public transport with good guidance.	6.187	0.882	-0.973	0.520	5.962	0.966	-0.631	-0.318
	Behavioral intention to use (Cronbach's α = 0.803)								
BIU1	I expect to use smart public transport when available.	6.081	0.981	-1.183	1.314	5.964	0.910	-0.718	0.210
BIU2	I plan to use smart public transport when available.	6.106	0.856	-0.829	0.672	5.923	0.936	-0.968	1.789
BIU3	I will use smart public transport if I can access it.	6.225	0.828	-0.793	-0.078	5.980	0.958	-0.650	-0.157
BIU4	I will recommend smart public transport to people close to me when available.	5.935	0.971	-0.714	0.023	5.801	0.969	-0.425	-0.526

Note: SD denote standard deviation, SK denote skewness, KU denote kurtosis.

CHAPTER V
CONCLUSION AND RECOMMENDATIONS

The rapid demographic transformation of Thailand into a super-aged society presents unprecedented challenges and opportunities for public transportation systems. As the elderly population is projected to exceed 28% by 2040, understanding their service quality expectations, loyalty determinants, and behavioral intentions toward both traditional and smart public transportation becomes crucial for developing inclusive and sustainable mobility solutions. This thesis addresses these critical needs through comprehensive structural equation modeling approaches, examining the complex relationships between service quality dimensions, passenger loyalty, and behavioral intention to use among elderly populations across urban and rural contexts in Thailand.

This study realizes the importance of developing elderly-specific transportation frameworks that accommodate both traditional service quality considerations and emerging post-pandemic requirements. The findings provide essential guidelines for transportation operators, policymakers, and technology developers to create age-friendly public transportation systems that effectively serve Thailand's aging society while achieving sustainability objectives. Thus, This thesis is summarized to address the research objectives mentioned in Chapter 1, which comprise four main points as outlined below.

5.1 Service quality dimensions influencing elderly passengers' expectations toward sustainable public transport

Study 1: This research applied second-order confirmatory factor analysis to examine measurement invariance of sustainable public transport service quality expectations between urban and rural older adults in Thailand. The empirical results demonstrated successful measurement invariance across eleven service quality dimensions, confirming that the factor structure operates equivalently across urban and rural contexts. The validated framework incorporates nine traditional dimensions (Vehicle, Bus Stop, Accessibility, Convenience, Information, Staff, Safety and Security, Reliability, and Affordability) and two novel post-pandemic dimensions (Older's Facilities and Post-Pandemic Prevention). Universal priorities emerged for Convenience, Staff quality, and Reliability across both contexts, while rural elderly showed elevated importance for Safety and Security compared to urban counterparts. These findings establish empirical support for incorporating age-inclusive design and health protection measures as permanent components of sustainable transport planning, providing essential guidance for developing unified national standards while accommodating regional variations.

5.2 Determinants of elderly passenger loyalty in Thailand's public transportation

Study 2: This study investigated factors influencing public transportation loyalty among Thailand's elderly population from a post-pandemic perspective using Structural Equation Modeling. Data collected from elderly participants across Thailand's five regions revealed that passenger trust, passenger commitment, and perceived value were the strongest direct predictors of loyalty, while perceived service quality demonstrated a strong effect on trust formation. The analysis confirmed the majority of hypothesized relationships, with alternative attractiveness being the only non-significant factor. These findings emphasize the critical importance of the service quality-trust-loyalty pathway and highlight that specialized facilities for elderly passengers and post-pandemic prevention measures have become integral components of service quality perceptions, guiding transportation providers in developing effective strategies to enhance elderly mobility and social participation in Thailand's rapidly aging society.

5.3 Comparison of elderly intention to use smart public transportation between urban and rural areas

Study 3: This study examined elderly behavioral intention to use smart public transport systems across urban and rural Thailand through an integrated Technology Acceptance Model (TAM) and Theory of Planned Behavior (TPB) framework. Using data from elderly participants across both urban and rural contexts, the results demonstrated strong empirical support for all hypothesized relationships across both contexts. Perceived usefulness emerged as the strongest predictor of attitude formation in both contexts, while rural elderly exhibited enhanced sensitivity to ease of use considerations, stronger social influence effects, and greater importance of perceived behavioral control compared to urban counterparts. Urban elderly demonstrate superior ability to recognize technological benefits while maintaining more balanced factor influences. The measurement invariance testing confirmed construct equivalence across groups, supporting meaningful cross-group comparisons and revealing that rural elderly require more intuitive interfaces and comprehensive social support systems, while urban elderly can accommodate more sophisticated technological features.

5.4 Measurement models of elderly public transportation service quality and behavioral intention

Study 1: Measurement model of elderly expectations toward sustainable public transport service quality. This model features 11 dimensions, including nine traditional factors: "Vehicle", "Bus Stop", "Accessibility", "Convenience", "Information", "Staff", "Safety and Security", "Reliability", and "Affordability", plus two post-pandemic dimensions: "Older's Facilities" and "Post-Pandemic Prevention".

Study 2: Structural equation modeling was applied to examine loyalty determinants among elderly passengers. This comprehensive model incorporates nine key constructs: "Expected service quality", "Perceived service quality", "Perceived value", "Passenger satisfaction", "Passenger trust", "Passenger commitment", "Alternative attractiveness", "Switching costs", and "Passenger loyalty".

Study 3: Integrated TAM-TPB model was used to analyze elderly behavioral intention toward smart public transportation. This model features six main constructs: "Perceived ease of use", "Perceived usefulness", "Attitude toward smart public transport", "Subjective norm", "Perceived behavioral control", and "Behavioral intention".

5.5 Recommendations and Policy Implications

The aim of this study was to identify key factors related to elderly passengers' expectations, loyalty, and behavioral intentions toward public transportation systems in the context of Thailand's aging society. The findings serve as a basis for developing effective transportation services and smart systems tailored to the needs of elderly users in both urban and rural contexts. The recommendations and policy implications are summarized in three main points as follows:

5.5.1 Elderly-Specific Service Quality Development

The measurement invariance analysis confirms that transportation operators should prioritize universal dimensions while addressing context-specific needs. Based on the highest loading factors across both urban and rural contexts, the following priorities emerge:

5.5.1.1 Universal Priority Dimensions

Convenience emerged as the strongest predictor in the service quality framework, with standardized loadings of 0.890 (urban) and 0.858 (rural). Transportation providers should focus on:

1) Enhancing multimodal connectivity to facilitate seamless transfers between transport modes.
2) Improving boarding and alighting infrastructure with low-floor buses, adequate handrails, and non-slip surfaces.
3) Providing convenient luggage storage solutions tailored to elderly passengers' mobility constraints.

Staff quality demonstrated high importance with loadings of 0.871 (urban) and 0.850 (rural). Investment in human capital should include:

1) Comprehensive training programs emphasize empathy, patience, and age-sensitivity in service delivery.
2) Clear protocols for assisting elderly passengers during boarding, alighting, and emergencies.
3) Regular performance evaluations focused on elderly-friendly service behaviors.

Reliability showed consistent importance across contexts with loadings of 0.871 (urban) and 0.823 (rural). Operators should:

1) Implement real-time schedule adherence monitoring systems.
2) Establish punctuality standards with transparent performance reporting.
3) Develop contingency protocols to minimize service disruptions that disproportionately affect elderly passengers.

5.5.1.2 Context-Specific Priorities

Safety and Security demonstrated higher loading in rural areas (0.811) compared to urban areas (0.792), indicating enhanced rural concerns. Rural service improvements should emphasize:

1) Enhanced lighting at bus stops and along access pathways.
2) Security personnel or surveillance systems at isolated rural stops.
3) Emergency communication systems are accessible to elderly passengers with limited technological literacy.
4) Non-slip surfaces and obstacle-free zones at rural bus stops where infrastructure may be less developed.

5.5.1.3 Post-Pandemic Integration

Both Older's Facilities (urban: 0.777, rural: 0.690) and Post-Pandemic Prevention (urban: 0.602, rural: 0.606) should be integrated as permanent service components. Essential features include:

1) Priority seating with adequate spacing and enhanced accessibility.
2) Improved ventilation systems and air quality monitoring.
3) Clear visual and audio information systems accommodate age-related sensory decline.
4) Hygiene protocols include regular sanitization, hand hygiene facilities, and health screening capacity during outbreak periods.

5.5.2 Loyalty Enhancement Strategies

The structural equation modeling reveals critical pathways to elderly passenger loyalty, with trust serving as the pivotal mediating factor.

5.5.2.1 Trust-Building Through Service Quality

Perceived service quality dimensions with highest loadings include Convenience (0.778), Staff (0.778), and Reliability (0.784). The strong service quality-trust-loyalty pathway indicates that operators should:

1) Ensure consistent service delivery that meets or exceeds elderly passengers' expectations across all touchpoints.
2) Develop transparent communication channels that keep elderly passengers informed about service changes, disruptions, and improvements.
3) Implement feedback mechanisms specifically designed for elderly users, including non-digital options.
4) Demonstrate institutional integrity through honest acknowledgment of service failures and visible corrective actions.

5.5.2.2 Direct Loyalty Predictors

Passenger Trust (AVE = 0.646, CR = 0.880), Passenger Commitment (AVE = 0.577, CR = 0.845), and Perceived Value (AVE = 0.726, CR = 0.888) emerged as the strongest direct predictors of loyalty. Strategic initiatives should include:

1) Trust Development, All trust indicators showed strong loadings (0.779-0.829), suggesting operators should:

1.1) Maintain consistent service standards that build confidence in operator competence.

1.2) Foster personal connections between staff and regular elderly passengers.

1.3) Demonstrate concern for elderly passengers' safety and wellbeing beyond basic service provision.

2) Commitment Enhancement, The commitment dimension, particularly "public transport is an essential part of the public transportation system" (loading: 0.755), indicates operators should:

2.1) Communicate the societal and environmental benefits of public transport in terms resonating with elderly values.

2.2) Create community-oriented programs that foster pride in public transport usage.

2.3) Develop recognition programs acknowledging loyal elderly passengers' contribution to sustainable mobility.

3) Value Proposition: All three value indicators demonstrated strong loadings (0.847-0.856), suggesting pricing strategies should:

3.1) Offer flexible fare structures including discounted passes that clearly demonstrate cost savings.

3.2) Communicating values beyond price, emphasizing convenience, safety, and social benefits.

3.3) Consider means-tested subsidies acknowledging diverse economic circumstances among elderly populations.

5.5.2.3 Satisfaction Pathway

While passenger satisfaction showed moderate reliability (AVE = 0.490), its highest loading indicator was "Overall satisfaction" (0.836). This suggests that holistic service experience matters more than individual service aspects, requiring:

1) Integration of service improvements across all dimensions rather than isolated enhancements.
2) Regular satisfaction monitoring with elderly-specific metrics.
3) Service recovery protocols that address elderly passengers' concerns promptly and respectfully.

5.5.3 Smart Transportation Implementation Approaches

The integrated TAM-TPB model reveals distinct adoption patterns requiring differentiated implementation strategies across urban and rural contexts.

5.5.3.1 Universal Priority

Perceived Usefulness demonstrated strong influence on attitude formation in both contexts (urban: 0.813, rural: 0.795 for "reduces travel time"). All implementations should:

1) Clearly communicate practical benefits in terms relevant to elderly daily activities (healthcare access, social visits, shopping).
2) Provide comparative demonstrations showing time savings and convenience improvements over traditional systems.
3) Offer trial periods allowing elderly users to experience benefits firsthand without commitment.
4) Develop using case scenarios that resonate with elderly passengers' actual travel patterns and needs.

5.5.3.2 Rural-Specific Implementation

Rural elderly showed enhanced sensitivity to ease of use, with "easy to switch from other transportation modes" achieving the highest loading (0.877) compared to urban areas (0.887). Rural implementations require:

1) Intuitive Interface Design:

1.1) Simplified information display with minimal steps required to access critical information.

1.2) Large, high-contrast visual elements accommodating age-related vision changes.

1.3) Voice-activated options and tactile interfaces reduce reliance on fine motor skills.

1.4) Multi-language support including local dialects where appropriate.

2) Comprehensive Support Systems: Subjective norm showed stronger influence in rural areas (loadings: 0.835-0.923) compared to urban contexts (0.786-0.906), indicating:

2.1) Community-based training programs leveraging trusted local figures and peer educators.

2.2) Family involvement strategies where younger family members assist elderly relatives.

2.3) On-site assistance personnel at key locations during initial implementation phases.

2.4) Dedicated helplines with patient, elderly-friendly support staff.

3) Enhanced Perceived Behavioral Control: Rural elderly showed higher emphasis on "confident with good guidance" (loading: 0.829 vs. urban 0.697), requiring:

3.1) Comprehensive step-by-step instructional materials in both print and video formats.

3.2) Hands-on training sessions at community centers with practice opportunities.

3.3) Gradual technology introduction allowing progressive skill development.

3.4) Backup traditional options ensuring elderly passengers never feel stranded by technological difficulties.

5.5.3.3 Urban-Specific Implementation

Urban elderly demonstrated superior technological recognition with more balanced factor influences and stronger attitude formation (ATT loadings: 0.737-0.856 vs. rural 0.755-0.829). Urban implementations can:

1) Incorporate more sophisticated features including real-time tracking, multi-route optimization, and integrated payment systems.
2) Leverage existing technological familiarity for faster adoption.
3) Focus on efficiency benefits and time savings that resonate with urban lifestyles.
4) Provide advanced features while maintaining simple default modes.

5.5.3.4 Cross-Context Implementation Principles

Behavioral intention indicators showed consistent patterns with "will use smart public transport if I can access it" demonstrating highest commitment (urban: 0.702, rural: 0.732). This emphasizes:

1) Ensuring accessibility as the foundation of any smart transportation initiative.
2) Removing physical, economic, and knowledge barriers to access.
3) Creating multiple access pathways (mobile apps, kiosks, staff assistance, phone services).
4) Maintaining traditional alternatives during extended transition periods.

These comprehensive recommendations provide actionable guidance for developing inclusive, sustainable public transportation systems that effectively serve Thailand's rapidly aging society while contributing to broader sustainability objectives.

APPENDIX A

LIST OF PUBLICATIONS

List of publications

Chantaratang, A., Chonsalasin, D., Wisutwattanasak, P., Watcharamaisakul, F., Champahom, T., Ratanavaraha, V., & Jomnonkwao, S. (2025). Measurement Invariance of Expectations toward Sustainable Public Transport Service Quality among Urban and Rural Older Adults. **Civil Engineering Journal**. (Scopus: Q1, Impact Factor: 4.9). (In Press)

Chantaratang, A., Chonsalasin, D., Wisutwattanasak, P., Watcharamaisakul, F., Champahom, T., Ratanavaraha, V., & Jomnonkwao, S. (2025). Determinants of elderly passenger loyalty in Thailand's public transportation: a post-pandemic perspective. **Case Studies on Transport Policy**, 21, 101564. doi:https://doi.org/10.1016/j.cstp.2025.101564. (Scopus: Q1, Impact Factor: 3.3). (Published)

Chantaratang, A., Chonsalasin, D., Wisutwattanasak, P., Watcharamaisakul, F., Champahom, T., Ratanavaraha, V., & Jomnonkwao, S. (2025). A Comparison of Elderly Intention to Use Smart Public Transportation between Urban and Rural Areas in Thailand: An Integrated TAM–TPB Model. **Research in Transportation Economics**. (Scopus: Q1, Impact Factor: 3.4). (In Press)

BIOGRAPHY

Mr. Anon Chantaratang was born on June 21, 1991, in Mueang district, Nakhon Ratchasima province, Thailand. He completed his secondary education at Ratchasima Witthayalai School and graduated in 2009.

He pursued higher education at Suranaree University of Technology, earning his bachelor's degree in 2013 and master's degree in 2016, both in transportation engineering. Following his graduate studies, he gained professional experience working as a transportation and traffic engineer at Meinhardt (Thailand) Ltd. from 2016 to 2018.

In 2018 he transitioned to academia, joining Rajamangala University of Technology Isan as a lecturer in logistics technology program, Faculty of Sciences and Liberal Arts, a position he continues to hold. Seeking to advance his academic qualifications and research expertise, he enrolled in the Doctor of Philosophy program in industrial and logistics management engineering at Suranaree University of Technology in academic year 2022.

His doctoral research focuses on the development of structural equation modeling for service quality and behavioral intentions in regional public transportation for elderly populations in Thailand, contributing to the understanding of transportation needs in aging societies. His published works are presented in Appendix A.