Title	Deployment of Co-Creative Smart Mobility Systems for Sustainable Urban Development
Author(s)	周, 純甄
Citation	大阪大学, 2025, 博士論文
Version Type	VoR
URL	https://doi.org/10.18910/101680
rights	
Note	

Doctoral Dissertation

Deployment of Co-Creative Smart Mobility Systems for Sustainable Urban Development

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December 2024

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Acknowledgements

Completing a PhD dissertation has been the most challenging thing I have faced in my life so far. Earning a PhD degree is an accomplishment that stays with you forever. It demands persistence, analytical thinking, and effective time management and decision-making. Throughout the numerous trainings among this process, I have honed my mindset and plan to apply these skills in my future professional career and personal life. This journey just like a rollercoaster having peaks and valleys, each phase teaching me more about myself and the world around me.

This PhD dissertation required a comprehensive approach that I could not have developed alone. First and foremost, I would like to extend my heartfelt thanks to my supervisor, Prof. Kenji Doi. Prof. Doi provided me with numerous opportunities to participate in projects and collaborative research. These experiences greatly enriched my understanding, broadened my perspective, and offered valuable practical insights beyond mere conceptual hypotheses. Prof. Doi is not only an excellent coordinator but also attentive to my pace, guiding me in the right direction and providing opportunities that matched my abilities. Through the collaboration with him, I have grown significantly during my graduate studies.

I am grateful to Assoc. Prof. Katsuhiro Iida, not only for his role as a reviewer of my PhD dissertation but also as a guiding advisor in our lab. His keen insights during our lab meetings were invaluable, helping me to uncover and refine details I had missed and greatly elevating the quality of my work. His guidance was also important during my doctoral journey.

I am immensely thankful to Prof. Masanobu Kii and Assoc. Prof. Pawinee Iamtrakul for their co-supervision of my PhD studies. My participation in the Osaka University Honors Program allowed me the privilege to learn from Prof. Kii during a lab rotation. His profound research acumen and comprehensive insights were instrumental in helping me objectively evaluate my own research outcomes. His meticulous review significantly enhanced the quality of this dissertation.

As a visiting researcher, I had the unique opportunity to work under the guidance of Assoc. Prof. Pawinee Iamtrakul, Director of the Center of Excellence in Urban Mobility Research and Innovation at Thammasat University. Prof. Pawinee's precise and in-depth advice not only intensified my research but also facilitated a collaborative effort that led to the submission of our joint work to leading journals. This experience has been both enriching and inspiring.

During my PhD journey, I was fortunate to receive invaluable support from Assist. Prof. Yoh and Dr. Aoki. Dr. Yoh's dedicated assistance and Dr. Aoki's practical insights were pivotal in my research. Their active engagement and advice during lab meetings provided me with the guidance necessary to progress confidently in my work. Additionally, I must acknowledge the support from our secretary, Ms. Kajikawa, whose diligent assistance was indispensable throughout my studies.

I am also immensely grateful to the many experts and collaborators who supported my PhD journey. This work was bolstered by several significant research projects, notably the SATREPS

(JST/JICA) program led by Prof. Yoshitsugu Hayashi. Additionally, I deeply appreciate the support from the International Association of Traffic and Safety Sciences (IATSS), which played a crucial role in facilitating my research endeavors. Their contributions have been essential to the success of my doctoral studies.

In conclusion, I extend my deepest gratitude to everyone who contributed to my PhD journey. This includes all my lab members, whose camaraderie and support provided a foundation of encouragement and motivation. I am also thankful to all the members of our research projects, whose collaborative spirit and shared expertise enriched my experience and learning. My heartfelt thanks go to each one of you for your invaluable contributions and for being part of this significant chapter of my life.

Chun-Chen

Contents

1 Introduction

1.1 Background

Public transport plays a vital role in supporting high-density, mixed-use developments by enabling the efficient movement of people within cities. Its integration with land use planning, environmental benefits, and contribution to social equity makes it a cornerstone of urban planning and policy-making, ensuring long-term viability for growing urban populations. However, urban challenges such as depopulation, connectivity and accessibility gaps in public transport systems, and the last-mile problem present significant difficulties for city planners. These challenges cannot be addressed solely through public transport solutions.

The increasing focus on mobility research stems from the urgent need to tackle issues related to sustainability, equity, and accessibility, while leveraging opportunities to create smarter, safer, and more inclusive transport systems (International Transport Forum, 2024). Mobility research has become central to efforts aimed at improving quality of life, fostering community cohesion, and achieving environmental sustainability in increasingly interconnected cities (City of Lincoln, 2023).

Within an integrated transportation system, various transport modes and mobility services serve distinct roles. Emerging services like shared micro-mobility, ride-sharing, and on-demand transit, complement public transport networks by enhancing accessibility, bridging connectivity gaps, and addressing first- and last-mile challenges. These services contribute to the development of seamless, multimodal networks that promote efficient, inclusive, and sustainable urban mobility. A well-connected multimodal public transport system supports regional sustainability goals by helping to maintain population levels and regional vitality (Horiike et al., 2023).

However, the viability of such systems in low-demand areas is often compromised by the high costs associated with infrastructure, maintenance, capacity, and speed requirements. In these areas, diverse mobility options can support public transport by meeting varied user needs, enhancing last-mile connectivity, and fostering community-focused mobility solutions. (Nakase et al., 2021).

Urban administrators are increasingly promoting these compact and lightweight vehicles as sustainable alternatives to personal car use, supporting urban sustainability goals by enhancing transportation options, promoting eco-friendly landscapes, and alleviating urban traffic congestion (Aman, Zakhem, & Smith-Colin, 2021). They serve as more affordable options that are responsive to dynamic demand and changing mobility preferences (Schwinger, Tanriverdi, & Jarke, 2022).

Despite the introduction of emerging mobility solutions in developed urban contexts, developing countries, particularly motorcycle-dependent regions, face unique challenges. In Southeast Asian countries, motorcyclists represent 80% of road users (ASEAN NCAP, 2020), and 90% of global road fatalities occur in low- and middle-income countries, which have about 60% of the world’s vehicles

(World Health Organization, 2021). Key barriers in these countries include a lack of road safety awareness, regulatory non-compliance, and limited enforcement. The road traffic issue affects not only individuals but also all traffic participants, with serious implications for national economies. Previous research has evaluated the economic costs and benefits of road safety interventions, suggesting that securing mobility safety is essential for societal and environmental welfare. Safe and efficient mobility improves access to opportunities and freedom in daily life, engaging residents and local communities in creating value for safer mobility.

Recognizing both the benefits and challenges of sustainable mobility development and system management, this study aims to inform creating new mobility systems that promote inclusivity and sustainability, considering the co-evolution of mobility technologies and human users. Specifically, this study develops hypotheses and collects data across different environmental and societal contexts, verifying these hypotheses in various contexts, including both developed and developing urban areas.

1.2 Literature Review and Problem Statement

This study begins with a brief literature review to identify research gaps corresponding to each research question, helping to define research directions. Detailed reviews related to methodology and hypothesis development are elaborated in subsequent chapters.

1.2.1 Investigating Factors Influencing the Adoption of New Mobility Options

Attitudes significantly influence travel behavior, just as travel behavior can shape attitudes in return (Kroesen, Handy, & Chorus, 2017). In marketing, value creation is a central concept for exploring consumer attitudes and developing new products and services. Smith and Colgate (2007) identified four primary types of value that provide a framework for addressing key research questions.

First, functional/instrumental value refers to the extent to which a product performs appropriate functions to fulfill customers' desired goals, such as reliability and effectiveness. Second, experiential/hedonic value concerns a product that creates experiences, feelings, and emotions for customers. For example, the travel industry focuses on creating emotional experiences to satisfy consumers' pursuit of pleasure and enjoyment. Third, symbolic/expressive value involves associating psychological meaning with a product. This self-oriented value means customers appeal to self-worth and give personal meaning to the product. Green intentions (e.g., carbon neutrality) fall into this category, as users feel a sense of accomplishment when adopting the sharing economy or electric mobility. Lastly, cost/sacrifice value refers to consumers' desire to minimize the costs and other sacrifices involved in the purchase, ownership, and use of a product.

Recent studies have investigated user intentions toward new mobility services by introducing the concepts of functional/instrumental and experiential/hedonic values (Schuitema et al., 2013). Empirical research conducted in different global cities has provided insights into these factors. In a large-scale survey across several major European cities, Curtale and Liao (2020) investigated users' acceptance and preferences for shared micromobility services. They found that performance expectancy, social influence, and hedonic motivation had the highest impacts on behavioral intention. Another study in Germany supported these results, emphasizing the role of hedonic values when adopting new micromobility services (Kopplin, Brand, & Reichenberger, 2021). It suggested that shared e-scooters were primarily viewed as entertainment rather than a significant mode of transportation, with the appeal of entertainment being a major motivation for users.

However, different results have been observed in other regions. A study conducted in Jakarta, Indonesia, found that hedonic motivation did not significantly affect e-scooter sharing adoption (Putri et al., 2021) Instead, facilitating conditions and performance expectations encouraged e-scooter sharing, revealing that users focused more on functional/instrumental attributes. These findings suggest that mobility adoption and acceptance vary by region and cultural background.

Based on the literature, this study conceptualizes three coordinates to approach the multifaceted nature of mobility services (**Figure 1.1**): speed, functionality, and consumer values. These suggested consumer values form the foundation for investigating user intention and social adoption of new mobility services.

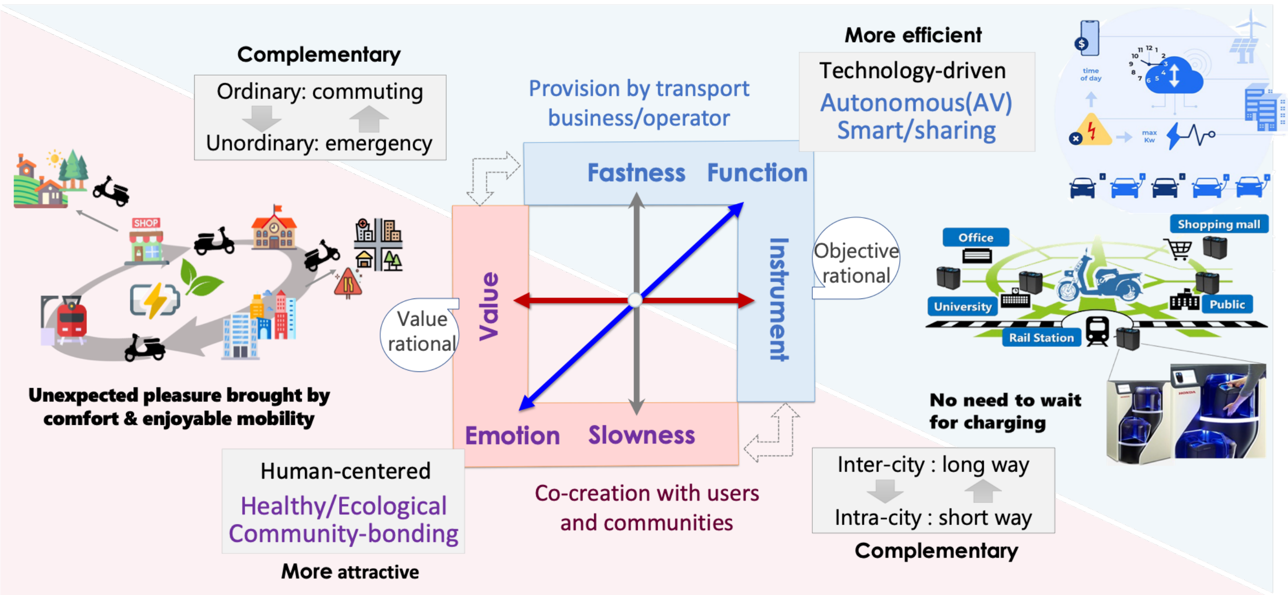

Figure 1.1 Three coordinates to approach the multiple nature of mobility service.

Assessing the Effects of Spatial Cognition on Mobility Travels

Small-format mobility services share similarities with active transport modes by fostering stronger connections between travelers and their environments (City of Lincoln, 2023). At the same time, they provide motorized flexibility for efficient spatial exploration. While experiential values are well-documented as key factors in mobility adoption (Curtale & Liao, 2020), the specific role of spatial experiences in shaping urban travel behaviors is less understood. This gap promotes to the question:

RQ1. How does users' spatial experience affect their urban travels?

Spatial cognition, a fundamental aspect of travel behavior, encompasses wayfinding, navigation, and route selection (Golledge & Gärling, 2004; Mondschein, Blumenberg, & Taylor, 2006). It is both influenced by and influences individuals' spatial experiences, shaping how they perceive and interact with their environments. Most transportation studies have focused on car drivers due to the dominance of automobiles in urban settings (Mondschein, Blumenberg, & Taylor, 2010).

Although some attempts have been made to incorporate human cognitive factors into transportation models, the effects of spatial experiences and varying levels of spatial knowledge are still insufficiently explored (Arentze & Timmermans, 2005a; 2005b; Manley & Cheng, 2018). A deeper understanding of how mode-specific experiences influence spatial cognition could significantly enhance transport modeling by introducing diverse matrices of activity opportunities (Mondschein et al., 2010). Studies have also investigated how different transport modes affect spatial knowledge, highlighting their varied impacts on cognitive development and travel behavior (Afrooz, White, & Parolin, 2018).

Cognitive maps—mental representations of the external environment formed through spatial experiences—play a pivotal role in navigation and interaction with surroundings. These maps influence decision-making, route planning, and overall travel behavior, making them indispensable for examining the relationship between spatial cognition and mobility (Mondschein et al., 2010). A comprehensive understanding of how transport modes shape cognitive maps could improve transport models, enabling better predictions of real-world activity patterns and enhancing their alignment with actual travel behaviors.

Despite its critical role, the lack of robust quantitative indicators for assessing individual spatial experiences in large- scale urban environments present a significant research gap. This study posits that users of small-format mobility services perceive their environments and behave differently compared to users of conventional private transport modes. To address this gap, the study empirically investigates the role of spatial experiences in shaping urban travel patterns. Specifically, it explores how traveling by small-format mobility influences users' spatial knowledge, how varying levels of spatial knowledge impact functional/instrumental and experiential/hedonic values associated with mobility experiences, and how spatial knowledge shapes urban travel patterns.

1.2.2 Understanding Behavioral Formation for Safer Mobility

In developed urban contexts, well-designed environments enhance drivers' experiential values by offering better cognitive opportunities for spatial exploration. Conversely, in developing contexts, underdeveloped infrastructure, complex traffic conditions, and immature traffic practices often result in unsafe riding habits and inappropriate behavioral responses. Understanding behavioral formation is crucial for promoting safer mobility, as it provides valuable insights into how individuals develop travel-related habits, attitudes, and decision-making patterns that directly impact on-road safety. This understanding forms the basis of our second research question:

RQ2. How can daily mobility be secured in motorcycle-dependent areas?

Motorcycle-dependent areas often suffer from a lack of formalized training and inconsistent safety measures, leading to high accident rates and risky riding behaviors. The Motorcycle Rider Behavior Questionnaire (MRBQ) has become a widely used tool for studying motorcyclists' behaviors (e.g., Uttra et al., 2020; Elliott et al., 2007). Risk perception plays a critical role in shaping behavior and influencing accident rates. However, perceptions of risk can vary significantly across regions, influenced by cultural, social, and environmental factors. Comprehensive reviews of regional experiences in motorcycle rider training and evaluations of interventions are provided by Haworth and Mulvihull (2005) and Araujo et al. (2017), respectively, highlighting how program content and effectiveness differ based on cultural contexts.

Traffic safety culture, which is defined as "shared patterns of behavior, shared norms prescribing certain road safety behaviors, and shared expectations regarding others' behaviors" (Nævestad, Laiou, Yannis, 2020), significantly influence motorcyclists' actions. Shared values toward road safety can foster a safer society, but they can also lead to risky behaviors due to false consensus. This underscores the importance of education in fostering a culture of safety and addressing misconceptions. Education has long been considered a cornerstone of accident prevention. Rider licensing and training programs aim to address the lack of experience, particularly for new riders.

Despite the presence of various training programs, there is often a discrepancy between the skills taught and the real-world challenges riders face, particularly in regions where informal learning prevails and many start riding at a young age with minimal formal guidance (Blackman & Haworth, 2010). This situation is particularly evident in developing countries (Woratanarat, 2013). Consequently, immature and risky behaviors remain leading causes of riding injuries (Wong, Chung, & Huang, 2010). While evaluations of motorcycle rider training programs often assess improvements in skills, risk-taking attitudes, and hazard perception, they frequently fail to identify gaps in course content. The extent to which training programs can compensate for a lack of experience remains unclear (Blackman & Haworth, 2013).

Existing questionnaires used for evaluating rider behaviors often lack universally defined constructs, include excessive items, and rely on exploratory methods, limiting their adaptability for cross-cultural comparisons and standardized evaluations. To address these issues, this study integrates psychometrics and cultural theory into a structured correlated model, enhancing our ability to understand and predict the behavioral formation of motorcyclists. This approach not only identifies key factors contributing to accidents but also helps in developing standardized questionnaires that enable cross-cultural adaptability and meaningful comparisons. By improving the evaluation of risk perception and driving behaviors, this study aims to support the creation of targeted, impactful safety interventions that are culturally and contextually appropriate.

All in all, addressing RQ2 involves a multifaceted approach that combines empirical research with practical interventions, aiming to secure daily mobility in motorcycle-dependent areas through enhanced understanding and support of behavioral changes towards safer riding practices.

1.2.3 Developing Behavioral Changes Toward Sustainable Mobility Options

Having explored how to secure daily mobility in motorcycle-dependent areas in RQ2, this study recognized the critical need for not only addressing safety but also enhancing sustainability in transportation system by behavior changes. Securing the safe use of current mobility options while encouraging the adoption of more sustainable alternatives is regarded a promising approach to advancing sustainable transport development. This recognition leads to the third research question:

RQ3. How can behavioral changes towards more sustainable mobility choices be promoted?

A pilot service aiming to promote more sustainable transport options utilizes an intervention-program approach to change travel behavior. This approach encourages people to try new behaviors and modify existing ones. Travel behavior interventions are commonly implemented to reduce private car use and encourage more sustainable transport options, such as developing infrastructure (e.g., cycling lanes, sidewalks), conducting public transport campaigns, or offering financial incentives (Javaid et al., 2022).

A review of approximately 400 global cases of behavioral interventions reveals that while these strategies can increase the intention to use sustainable travel modes—such as walking, cycling, and public transport—they often fail to achieve sustained behavior change. This is particularly evident in efforts to shift commuters from private cars to sustainable transport modes (Arnott et al., 2014; Javaid et al., 2022). This raises concerns about their limited effectiveness in reducing emissions.

In the literature, theories of behavior change have been widely utilized to support interventions (United Nations Development Group, 2017). The Theory of Planned Behavior (TPB, Ajzen, 1985) is a dominant framework, focusing on the factors influencing decision-making during the pre-intervention phase. However, TPB lacks the ability to explicitly explain the cognitive processes behind behavioral change or how specific alternatives are chosen (Adjei & Behrens, 2012). This limitation highlights the need for theoretical innovation to better understand and construct effective models for travel behavior change (Adjei & Behrens, 2012).

This study aims to addresses this gap by proposing an integrated model to elucidate how specific interventions contribute to developmental behavioral changes, grounded in empirical evidence. The focus is on encouraging mobility users to replace private car usage with community-based ride-sharing services. Community-based electric car sharing is a proposed sustainable transport mode that enhances access to public transportation in areas lacking diverse and affordable mobility options (Herman, 2022). Previous initiatives have shown promising results, including increased public transit use, walking, and cycling, leading to a 44% reduction in average vehicle miles traveled and abandoned plans to purchase private vehicles (Forth, 2020). Furthermore, electric car sharing reduces emissions by up to 43% per user compared to gasoline-powered travel (Nicholas & Bernard, 2021), promoting clean, economical, and safe mobility while mitigating health issues and reducing lengthy commutes.

The proposed model specifically investigates two aspects: the factors influencing travelers' intention to try the service during the pre-intervention phase and the factors that sustain this intention, leading to long-term behavioral change. By examining these mechanisms, this study aims to provide deeper insights into what drives sustained user engagement and commitment, fostering meaningful and lasting behavior change resulting from the intervention.

1.2.4 Clarifying Happiness-Oriented Mobility Choices to Enhance Well-Being

As urban environments continue to evolve, the integration of advanced mobility technologies presents opportunities to transform city lifestyles. Cultural context significantly influences how residents perceive and adapt to these changes. Rapid technological advancements promise to revolutionize transport modes and have the potential to greatly enhance urban life for people in diverse urban settings. Given the profound impact these innovations can have, it is crucial to understand and assess their effects comprehensively. This necessity leads us to our fourth research question:

RQ4: How can mobility technologies enhance well-being?

In an era marked by rapid urbanization and technological transformation, mobility technologies are increasingly recognized for their significant impact on individual well-being and societal happiness (Vella-Brodrick & Stanley, 2013). Historically, transport planning has prioritized efficiency, cost, and environmental sustainability. However, the integration of happiness and well-being as core considerations in transport systems remains relatively underexplored.

Despite growing interest in the relationship between new technologies—such as the sharing economy and emerging mobility services—and well-being, significant challenges persist. Critics argue that the sharing economy often falls short of its ideals, functioning more as a marketing strategy to make profit-driven enterprises appear socially acceptable and community-oriented rather than genuinely promoting sharing principles (Arvidsson, 2018). Moreover, much of the existing research on sustainable transport predominantly focuses on environmental benefits, overlooking happiness-oriented factors such as autonomy, social connectivity, and perceived freedom, which play a crucial role in shaping user preferences.

Furthermore, while research into the effects of social conformity on service adoption is emerging

(Cherchi, 2017; Li et al., 2022), a comprehensive framework for evaluating the impact of mobility choices on well-being is still lacking. Bridging this gap is essential for advancing sustainable urban development and enhancing quality of life. A deeper understanding of how happiness-oriented mobility factors influence travel behaviors can guide the design of user-centered transport systems that promote public well-being through authentic choices. (Beverland & Farrelly, 2010).

By clarifying these dynamics, this research aims to contribute to the creation of more inclusive, equitable, and joyful mobility experiences, aligning with global sustainability and well-being goals. This approach ensures that as we develop new mobility technologies, they are not only operational efficient and environmentally sustainable but also aligns with public values, thus enhance the overall happiness for urban residents.

1.3 Research Objectives and Scope

The structure of the proposed dissertation chapters is depicted in **Figure 1.2,** and the research questions of this study are listed as follows.

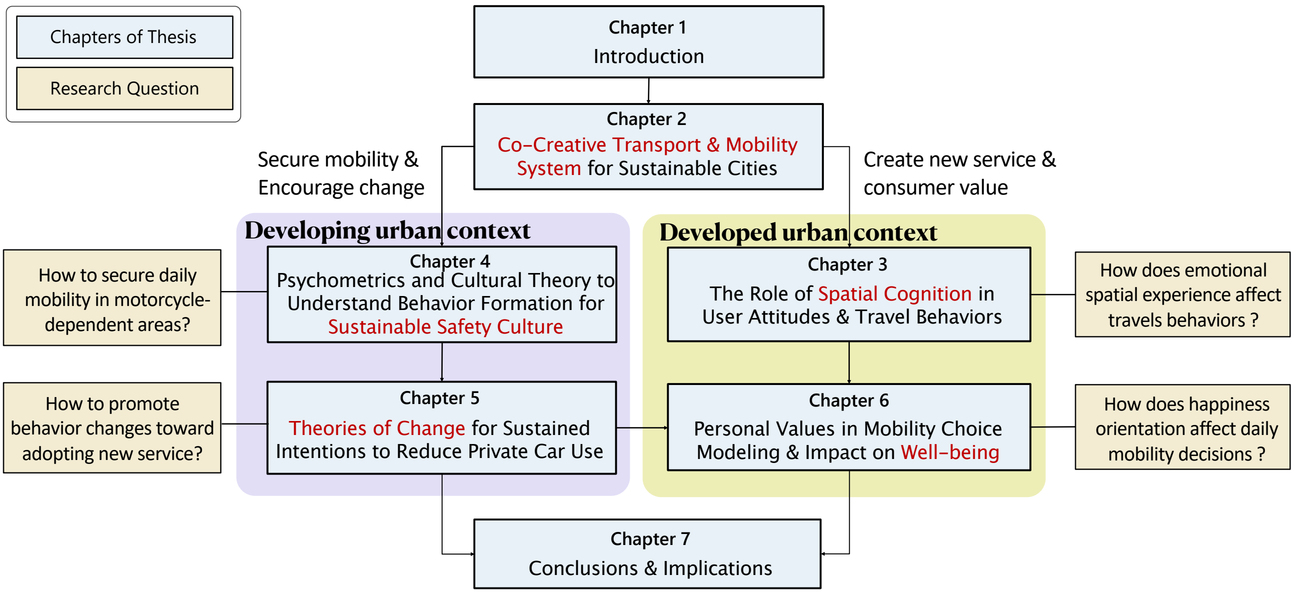

Figure 1.2 Structure of the dissertation chapters.

RQ1. How does users' spatial experience affect their urban travels?

RQ2. How can daily mobility be secured in motorcycle-dependent areas?

RQ3. How can behavioral changes towards more sustainable mobility choices be promoted?

RQ4. How can mobility technologies enhance well-being?

Chapter 2 Overview

Chapter 2 conceptualizes co-creative transport and mobility systems as a foundation for sustainable city development. In the post-pandemic era, evolving lifestyles and shifting values highlight the limitations of compact and high-density urban designs, necessitating a reimagining of urban frameworks. This chapter revisits the concept of milieu (Bevilacqua et al., 2014), an urban, community-centered space for residents, as a framework for shaping a new community-focused design. Building on this concept, the chapter introduces the vision of a resilient city capable of effectively functioning within both extraordinary systems (e.g., during disasters, pandemics, or crises) and everyday systems.

The proposed approach involves repurposing underutilized urban spaces and implementing temporal strategies to create new opportunities for daily activities and mobility. To explore this vision, two case studies were conducted to introduce resource-efficient spatial and temporal strategies were applied to transform underutilized urban spaces into vibrant urban centers, maximizing their social and economic value.

These strategies aim to address perceived urban challenges by converting problem areas into socio-economically valuable spaces. They also seek to enhance citizens' self-efficacy in daily transport and mobility while fostering compassion among stakeholders for cross-sector collaborative partnerships. Ultimately, the goal is to promote social well-being and sustainable urban development.

Chapter 3 Overview

Chapter 3 investigates the factors influencing small-format mobility users' attitudes and urban travel behaviors. Small-format mobility services, such as electric scooters and bikes, share key similarities with active transport modes by fostering stronger connections between travelers and their environments. At the same time, these services provide motorized flexibility, enabling efficient spatial exploration. However, the ways in which users' spatial experiences influence both instrumental/ functional and hedonic/experiential values—and how these values shape their adoption of such services—remain largely unexplored. This chapter builds on the literature surrounding cognitive affordance, focusing on how spatial knowledge enables travelers to seize cognitive opportunities for navigating urban spaces. By examining the interplay between spatial experiences and mobility values, the chapter aims to uncover the mechanisms that drive service adoption and sustained use. To achieve this, a mixed-methods approach is employed, integrating multiple data sources for deeper insights. Data collection was conducted through a social demonstration project involving a pilot service of battery-swappable electric two-wheelers in Osaka. These include:

- **Sketch Maps** to evaluate participants' spatial knowledge and navigation abilities.
- **Questionnaire Surveys** to capture users' attitudes, focusing on functional/instrumental and hedonic/experiential dimensions.
- **Panel Data Analysis** on activity-travel patterns to track behavior change over time.

This comprehensive analysis sheds light on the role of spatial cognition in shaping attitudes and behaviors, providing valuable implications for the design of user-centered, sustainable mobility systems.

Chapter 4 Overview

Chapter 4 delves into the underlying constructs that shape behavior formation, with a focus on securing the safety of daily mobility. While small-format electric mobility solutions are gaining popularity in developed urban contexts, developing countries—particularly those with a high reliance on motorcycles—face distinct challenges in achieving sustainable and safe mobility. This chapter applies psychometric frameworks and cultural theories to understand the formation of drivers' behaviors. By examining how individuals perceive and respond to risks within their cultural contexts, this approach provides a understanding of behavioral drivers and their implications for road safety.

The chapter begins with a critical reflection on the authors' previous work conducted in Vietnam, highlighting key findings and gaps. Building on these insights, the methodology is updated to incorporate a broader cultural lens. A large-scale questionnaire survey of motorcyclists (sample size: 1,200) was conducted in Thailand to explore these constructs further.

The incorporation of psychometric and cultural frameworks offers a robust approach for identifying behavioral patterns and risk perceptions. This perspective not only deepens understanding of driver behavior formation but also supports the development of culturally adaptable and effective safety interventions.

Chapter 5 Overview

Chapter 5 develops theories of change to sustain behavioral intentions toward adopting sustainable mobility options as substitutes for private cars. Interventions are often employed to encourage behavior changes toward sustainable modes such as cycling, walking, or public transport. However, empirical evidence shows that these interventions typically fail to sustain long-term behavior change, limiting their overall effectiveness. To address this challenge, this chapter identifies present gaps in behavior model research through an intensive literature review, and integrates the conventional Theory of Planned Behavior with Goal-Framing Theory from environmental psychology to investigate the underlying decision-making mechanisms that influence travelers' choice of travel mode. Data collection was conducted through a pilot project of small-format electric ride-sharing in Bangkok, Thailand, and statistical causation analysis was employed to test the proposed hypotheses. The integrated model identifies key psychological factors that shape behavior while also providing insights into how behaviors evolve over time through goal pursuit.

Chapter 6 Overview

Chapter 6 focuses on incorporating personal values into mobility choice modeling and examining their impact on well-being. The growing adoption of electric vehicles and car-sharing services is reshaping urban landscapes by fostering environmental sustainability, enhancing social equity, and driving cultural shifts toward more sustainable mobility practices. While social trends significantly influence individual choices, these dynamics can manifest in two contrasting ways: on one hand, they may encourage greater conformity with societal norms, prompting individuals to adopt behaviors aligned with mainstream mobility practices. On the other hand, they may highlight the importance of authentic mobility choices, where individuals prioritize decisions that reflect their unique personal values, preferences, and lifestyles.

Building on earlier discussions about the role of personal values in shaping individual decisions, this chapter employs Latent Class Choice Modeling (LCCM) to investigate how these values influence decision-making across varying service levels in different mobility options. The study examines the relationship between travelers' mobility preferences and their orientation toward happiness, conceptualized as a guiding principle for achieving desired lifestyles and well-being. Specifically, it explores the interplay between authenticity and conformity in mobility choices, focusing on decisions related to car ownership versus car-sharing and preferences for gasoline versus electric vehicles.

To provide empirical evidence, a survey was conducted in Japan, considering variations based on city size. The survey collected 1,200 valid responses, offering robust insights into how personal values drive mobility choices and their implications for well-being in diverse urban contexts.

2 Conceptualizing Co-Creative Transport and Mobility Systems for Sustainable Cities

Summary: This chapter addresses the urgent need to transform conventional cities into flexible, self-sufficient urban environments capable of responding effectively to crises and maintaining functionality during normal times. A resilient and sustainable city is conceptualized as one that operates effectively in three key dimensions: (1) Balancing Life Protection and Urban Functionality, (2) Aligning Global Objectives with Regional Goals, and (3) Harmonizing Extraordinary and Everyday Systems.

To achieve this vision, the chapter introduces a community-centered urban design framework that prioritizes well-being, even in the "new normal." Central to this framework is the concept of the milieu, which underscores the importance of local places and innovation by incorporating underutilized urban void spaces into a city's socio-economic fabric. The chapter also proposes the concept of a self-sustaining, segmented city supported by a well-connected multi-modal transport and mobility system. This framework is designed to address emergencies effectively by enhancing citizens' self-efficacy and fostering compassion and collaboration among diverse stakeholders.

Building on analyses of case studies in Japan, this chapter highlights resource-efficient strategies that leverage spatial and temporal opportunities in public transport systems. These strategies demonstrate how public-private partnerships and collaborative efforts among industry, government, and private stakeholders are already driving the emergence of new, resilient local urban designs.

*This chapter is a version of the following publications: **Chou, C. C.**, Aoki, Y., Yoh, K., & Doi, K. (2021). New local design in the new normal: Sustainable city for outbreak risk. IATSS research, 45(4), 395-404; **Chou, C. C.**, Doi, K., Kii, M. (2024). Time Wealth as a Determinant of Public Transport Behavior: Empirical Evidence from Japan. 2024 International Conference and Annual Meeting of the Chinese Institute of Transportation, Taichung, Taiwan.*

2.1 Introduction

The 2019–2021 COVID-19 pandemic brought significant lifestyle changes, including the widespread adoption of remote work, virtual meetings, digital and contactless payment systems, and a growing preference for local travel and tourism (Tokyo Metropolitan Government, 2021). These adaptations, collectively termed the "new normal," illustrate how societies integrate transformative changes into daily routines, reshaping urban demands. However, these changes are unlikely to endure unless they align with rational, long-term preferences. As fear and anxiety subside, socio-economic conditions may revert to pre-pandemic norms, indicating that the message of fear has a limited, short-term influence on driving lasting behavioral change.

The pandemic also acted as a catalyst for rethinking urban demands and spurred reflections on innovative approaches to city and mobility design. In many countries, economic growth has historically driven urban planning based on the separation of work and residence, resulting in the expansion of low-density suburbs where affordable housing is located. However, the pandemic has accelerated a shift towards integrating work and living spaces, with teleworking at home becoming increasingly common (Ishigami, Ohno, Kawate, 2020). As a result, the cost of incorporating workspace into living areas has emerged as a new consideration in housing preferences. Additionally, there is growing demand for residences that not only provide proximity to essential commercial facilities but also improve well-being by offering access to cultural, entertainment, and health-related facilities, as well as parks and pedestrian-friendly environments.

A sustainable city can be defined as an urban space that is designed, developed, and managed to balance environmental, social, and economic goals while ensuring long-term well-being for its residents (Wheeler, 2013). These urban spaces are dynamically shaped by the activities and movements of their inhabitants. Within this framework, cities can be understood through three distinct dimensions: cyber, urbs, and civitas. The term "cyber" refers to elements related to information technology, the internet, and virtual reality. In the context of urban planning, it represents the digital infrastructure and technologies that support the functioning of modern cities. "Urbs," a Latin term for city, focuses on the physical aspects of urban environments, such as architecture, roads, and public spaces. "Civitas," another Latin term, encompasses the legal and social aspects of being part of a community. It emphasizes social life and community engagement, which define the cultural and operational characteristics of a city.

These concepts together provide a holistic view of contemporary urban life, where physical spaces are increasingly intertwined with digital technologies. Digital technologies, like digital twins, offer environments that reflect and simulate the physical world, serving as crucial fields for decision-making. Moreover, civic life is influenced by both the built environment and digital interactions. This integrated perspective is essential in discussions about sustainable cities, where digital technology (Cyber) enhances the quality and performance of urban services (Urbs), while ensuring that the needs of the community (Civitas) are met. The synergy between Cyber, Urbs, and Civitas enhances urban well-being by creating environments that are technologically advanced, physically robust, and socially inclusive. This integration is crucial for developing sustainable, resilient, and thriving urban areas.

As illustrated in **Figure 2.1**, changes in lifestyle drive shifts in activities and movements, necessitating a corresponding transformation in urban space. These spatial changes are expected to further influence behaviors and activities. The integration of a city's physical components, including spatial environments and human activities, with cyber technologies has the potential to reduce the inertia of change. Information and Communication Technology (ICT), Intelligent Transport Systems (ITS), and Mobility as a Service (MaaS) are already helping municipalities improve infrastructure, efficiency, and quality of life for both residents and visitors.

Figure 2.2 presents a triangular framework, representing the interrelated dimensions of urban design. To flexibly address unpredictable future risks, cities must integrate the characteristics of a people-centered creative city (i.e., civitas), an autonomous and segmented compact city capable of responding to lockdowns (i.e., urbs), and a smart city enabled by digital technologies to facilitate risk communication (i.e., cyber). Effective risk communication is crucial for reducing societal risks and requires the transparent sharing of accurate information among governments, experts, businesses, and citizens, as well as within individual districts and neighborhoods. This integration calls for the formation of a new "field" where the elements of civitas, urbs, and cyber converge to create resilient, adaptable urban environments.

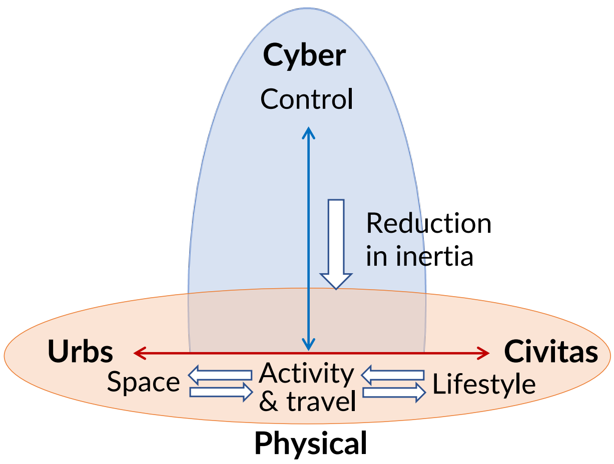

Figure 2.1 Components of a city.

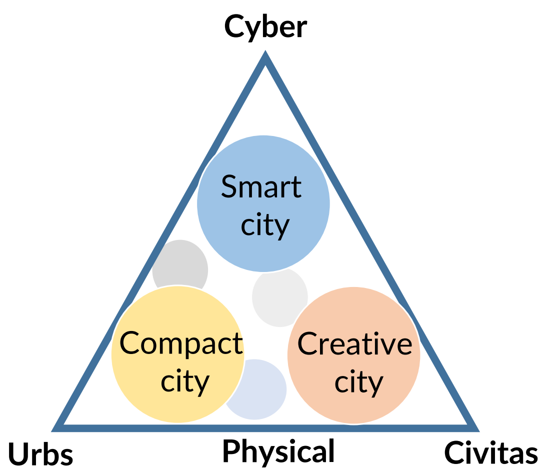

Figure 2.2 Various model of city form.

The formation of these "fields" offers valuable insights for building sustainable cities capable of withstanding disasters and managing risks. This involves supporting urban functions by:

(1) **Balancing Life Protection and City Functions**: Striking a balance between safeguarding individual lives and maintaining societal well-being and city operations.

(2) **Aligning Global and Regional Goals:** Reconciling global objectives, such as the SDGs and carbon neutrality, with local development goals that preserve historical and cultural contexts.

(3) **Harmonizing Extraordinary and Everyday Systems**: Integrating systems designed for unpredictable outbreaks with those used in daily life.

These objectives often present trade-offs, making it challenging to achieve win-win solutions. To address this, this paper proposes a conceptual framework for a co-creative transport and mobility system aimed at supporting local development for sustainable cities. As illustrated in **Figure 2.3**, the new normal requires meta-designs that connect civitas (community and society), urbs (urban infrastructure), and cyber (innovative technology) to enhance happiness and improve well-being.

In **Figure 2.3**, the concept of mental infrastructure is introduced as a complement to the physical infrastructure of a city. Mental infrastructure in the context of urban planning refers to the cognitive and psychological frameworks that influence how individuals and communities perceive, interact with, and shape their environments. It encompasses a range of factors including cultural norms, values, beliefs, knowledge systems, and collective memories that contribute to the social and psychological foundations of a community. For example, a community's readiness to adopt sustainable practices or new technologies can hinge on the prevailing mental infrastructure. Urban planners need to consider these psychological and cultural aspects to effectively design spaces that are not only functional but also resonate well with the inhabitants' way of life and aspirations. This consideration helps in creating urban environments that are sustainable, inclusive, and adaptable to the needs of their diverse populations. Markus (2015) highlighted mental infrastructure act as systems that ensure safety and security, protect individuals' self-esteem, and foster innovation.

To address safety issues, it is essential to adapt lifestyles, including daily activities and mobility, at the civitas level. Simultaneously, urban spaces must evolve into autonomous, self-sustaining, and segmented structures at the urbs level. Leveraging cyber technologies can enhance communication, support inclusive practices, and enable what this study introduces as compassionate mobility.

Compassion, defined as a kind and caring emotional response that fosters shared understanding and authentic support (Neff & Seppala, 2016), has been shown to strengthen interpersonal connections and social commitment (Kanov et al., 2004). While compassion has been widely studied in fields like healthcare, this paper emphasizes its role in mobility. Compassionate mobility offers self-supportive, sustainable transport alternatives that remain functional even during lockdowns. By linking transportation services with societal and community needs, it promotes inclusivity and sustainability, particularly for vulnerable groups (Aguila, 2019). Compassionate mobility not only connects urban cores but also enriches urban life by addressing individual health, well-being, and community resilience. This approach highlights its potential to support human resilience and community success under extraordinary circumstances, ensuring that cities remain adaptable, inclusive, and sustainable in the face of ongoing dynamics and future challenges.

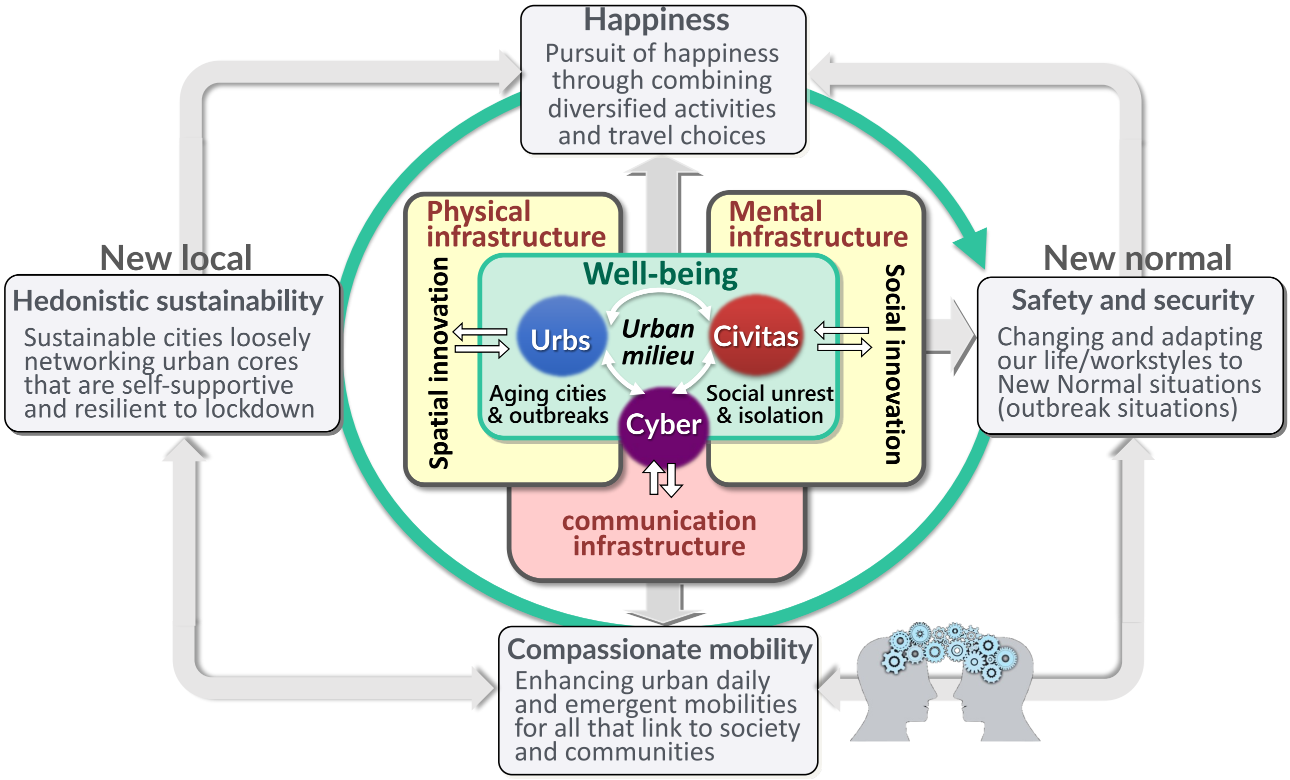

Figure 2.3 Meta-design framework for sustainable city development.

The urban milieu, as described by Bevilacqua et al. (2014), encompasses the complex social, cultural, and environmental fabric that defines the character and functionality of urban spaces. This concept is crucial for understanding how cities operate and evolve. Acting as the integrative core, the urban milieu interlinks the dimensions of Cyber, Urbs, and Civitas, ensuring a holistic approach to urban development and sustainability.

Positioning the milieu at the center highlights the necessity of considering all aspects of urban life when designing policies and interventions. This comprehensive perspective ensures that technological advancements (Cyber), physical layouts (Urbs), and social frameworks (Civitas) are coordinated to support not only the routine functioning of cities but also their capacity to thrive in times of crisis. This strategic centrality of the urban milieu emphasizes its importance in fostering an integrated, well-balanced urban development strategy.

This chapter revisits and focuses on the concept of the urban milieu, providing a foundational framework for subsequent discussions. Building on this foundation, we propose the concept of a resilient city that is capable of functioning effectively within both extraordinary systems and everyday systems. This vision includes repurposing underutilized urban spaces to create new opportunities for daily activities and mobility, thereby transforming perceived problem areas into socio-economically valuable spaces while enhancing citizens' self-efficacy in daily transport and mobility. To further explore the practical applications of this concept, the paper examines two case studies of transportation machizukuri in Japan (Mwebesa, Yoh, & Doi, 2021). Machizukuri, a Japanese urban planning approach, combines “Machi” (community or small area) and “Zukuri” (building, creating, and planning) to emphasize collaboration between local residents and government entities in creating livable, sustainable cities tailored to residents’ needs.

Furthermore, the interactions and synthesizing effects among the Cyber, Urbs, and Civitas dimensions will be extensively explored in Chapters 3 to 6. These sections will delve into how these dimensions collectively contribute to urban resilience and examine strategies for fostering compassionate mobility. The aim is to enhance cities in a manner that is technologically advanced, physically robust, and socially inclusive, ensuring that urban environments not only support efficient and safe mobility but also foster a sense of community and accessibility for all citizens.

2.2 Spatial and Temporal Opportunities to Encourage Sustainable City

2.2.1 Transport-Oriented Design and its Challenges

Traditional urban design, particularly in the post-industrial age, has often been characterized by a transport-oriented approach that relies heavily on motor vehicle transportation. This model has profoundly influenced the urban landscape, particularly in North America and other regions that underwent rapid expansion during the 20th century. In contrast, recent decades have seen the emergence of Transit-Oriented Development (TOD), which aims to create sustainable, livable urban spaces that reduce reliance on cars, promote public transit, increase density, and enhance residents’ quality of life through mixed-use developments and improved pedestrian and cycling infrastructure.

However, areas with low demand for public transport, particularly in regions facing declining populations, rural migration, and aging demographics—such as in Japan—continue to struggle with sustainability challenges (Kii et al., 2021). These factors lead to a vicious cycle where diminishing ridership results in reduced revenue, prompting further cuts in service provision, thereby exacerbating the decline. In response, strategies to enhance public transport satisfaction have been implemented, which often involve improving the level of service despite the constraints of increasing costs.

Scholars like Von Jorck et al. (2019) and Geiger et al. (2021) have introduced the concept of “time wealth,” which incorporates qualitative factors that influence how people perceive and value their time. Our empirical research (Chou et al., 2024), drawing on recent definitions from Vitrano and Mellquist (2023), explored time wealth as a key determinant of public transport behavior. We focused on three critical dimensions: chronometric (whether users can complete their journeys within available time), synchronization (whether schedules align with users’ needs), and sovereignty (whether users can make flexible decisions without being constrained by rigid schedules). The findings show that time wealth functions as a fundamental factor in facilitating behavioral intention in using public transport. These factors are crucial for coordinating and integrating spatiotemporal urban planning strategies to enhance urban living.

The well-integrated and connected urban milieu, with efficient public transport and accessible public spaces, significantly increases wealth in time—the discretionary time residents have after fulfilling essential duties, as suggested by Yamachi et al. (2023). Such environments reduce the need for lengthy commutes, enrich the quality of time spent in cultural and social activities, and promote healthier lifestyle choices through walkable designs. Additionally, smart technologies streamline daily routines, enhancing residents' control over their schedules and improving overall urban functionality. Collectively, these elements not only make urban living more efficient but also enhance the sovereignty residents have over their time, resulting in a more enjoyable and sustainable urban experience.

2.2.2 Redesign of a City

The concept of the "15-minute city," rooted in chrono-urbanism and advocated by Moreno et al. (2021), has gained renewed attention as a vision adaptable to both pandemic and post-pandemic urban living. This model envisions urban areas composed of diverse facilities within a 15-minute walk that fulfill essential daily needs, such as work, commerce, healthcare, education, and recreation. The core framework of this vision emphasizes proximity, diversity, density, and digital integration. Cities like Paris, which aims to realize the concept by 2024 (Moreno et al., 2021), and Melbourne, which has introduced a similar 20-minute city initiative focused on walking, biking, and public transportation (State Government of Victoria, 2021), demonstrate how traditional neighborhood scales can inspire strategies for urban resilience.

Both the 15-minute and 20-minute city concepts aim to create "short-way cities" through mixed land use (Scholz-Reiter & Grollmann, 2006). The four defining principles of the 15-minute city—proximity, diversity, density, and ubiquity—align with the 3D aspects of public transport-oriented development (density, diversity, and human-centered design) while integrating smart city ubiquity. Such design promotes compact, accessible, and tech-enabled urban living.

Afrin, Chowdhury, and Rahman (2021), through a literature review, highlighted critical elements of resilient urban design, emphasizing the importance of familiar public spaces. Using a disaster risk management framework, they proposed a three-stage urban strategy: response, mitigation, and preparedness. During the response stage, they stressed the role of smart and resilient urban design and policies to track and manage infections. The mitigation stage emphasized leveraging new technological approaches for managing current and future pandemics. At this stage, the integration of physical factors like urban access, infrastructure, and land use with socio-cultural, political, and economic considerations was considered essential. Finally, at the preparedness stage, they recommended proactive capacity-building measures to equip communities for future outbreaks. They also highlighted the need for self-sufficient, decentralized, and resource-efficient public spaces in familiar locations to address social distancing requirements at the city level.

The concept of "milieu" has also been explored extensively in urban planning (Camagni 1991a;

1991b; Bramanti & Ratti, 2019). It is broadly defined as “the people, physical, and social conditions and events that provide the environment in which someone acts or lives.” In the context of the innovative milieu, Camagni (1991a, 1991b) emphasized geographic and spatial proximity for fostering information exchange, cultural alignment, frequent collaboration, and dense mobility within a localized area. This “local milieu” acts as a synergistic venue for collective learning and mitigating uncertainty. However, internal relationships alone are insufficient for innovation. Camagni highlighted the importance of external networks, which complement local dynamics by fostering broader cooperation and innovation through connections beyond geographic confines. By combining these concepts, the spatial and temporal redesign of cities can enable both resilience and adaptability, ensuring vibrant urban living that supports community well-being and sustainability.

2.2.3 Utilizing Void Spaces around Transport Infrastructure

During the growth phase of urban development, transport planning has predominantly focused on enhancing mobility between city centers and suburbs, often through express transit systems. However, this approach has frequently neglected the “interspaces”—void or underutilized areas connecting railway stations—resulting in the creation of many scarcely used spaces within cities. For example, in Japan, elevated railway projects aimed at eliminating railway crossings and enhancing road safety have created new infrastructure spaces. While commercially viable sections near stations are often developed, void spaces further from stations are frequently left unused, serving as parking lots, storage areas, or restricted zones, thus diminishing the urban appeal along railway corridors. Similar issues are observed in China, where spaces beneath overpasses are often dark, unattractive, and abandoned (Sheng et al., 2018).

Meanwhile, Japan is experiencing an increase in vacant houses and lots in urban areas due to population decline. This phenomenon, termed the “sponge phenomenon,” involves random, unplanned occurrences of void spaces, such as vacant stores, shuttered shopping streets, and underutilized urban areas around transport infrastructure. These void spaces pose challenges for safety, crime prevention, and urban aesthetics, making planned responses difficult.

Recent studies have identified void spaces around transportation infrastructure as valuable resources for urban innovation. For example, Murakami (2013) examined the utilization of space under elevated railways between several stations in Kobe City. Initially regarded as traffic roads and unsuitable for residential or commercial use, these spaces were transformed into thriving streets through active collaboration among railway operators, the government, and local shop owners. Similarly, Doi (2018) analyzed transitions in the use of void spaces under elevated railway, emphasizing the importance of dialogue among stakeholders.

Nakamura and Muraki (2006) classified void space utilization in Tokyo based on factors like daytime population and land price, identifying untapped potential for underutilized sections. Kinoshita et al. (1999) also analyzed land use patterns under elevated railways in Tokyo, highlighting a shift toward open-space usage since 1985. They emphasized the importance of integrating void space development with broader urban planning efforts, involving operators, governments, and residents.

Utilizing these void spaces is also expected to generate psychological and community benefits. To enhance the usability and appeal of void spaces, especially under overpasses, addressing psychological safety concerns—such as territoriality, safety, and identifiability—is critical (Wang & Zhao, 2019). Improving these aspects can enhance the sense of security, identity, and comfort for users. Kido (2018) suggested that continuous infrastructure spaces, such as those along the Yamanote Line in Tokyo, could be transformed into attractive, multifunctional facilities that foster new community lifestyles, create vibrant promenades, and enhance well-being, particularly post-pandemic.

Collaborative systems are essential for sustainable development. Previous research emphasized the need for branding and sidewalk development in continuous infrastructure spaces along railway lines, advocating for stronger collaboration among citizens, governments, and railway operators (Momiyama & Soshiroda, 2020). Tanaka and Takamizawa (2010) further highlighted that railway companies focusing on enhancing the value of areas along their lines view void spaces as potential resources for increasing brand appeal, population retention, and connectivity. They stressed the importance of cooperative frameworks between railway operators and government entities to unlock the potential of these spaces.

Overall, void spaces around transportation infrastructure offer significant opportunities for urban innovation and community development. Transforming these areas requires coordinated efforts among railway operators, governments, and local communities to ensure sustainable use. By addressing user concerns and integrating void spaces into broader urban planning, these neglected areas can be revitalized to enhance urban functionality, safety, and well-being.

2.3 Conceptual Models

To facilitate a resilient and sustainable urban future, this study proposes a community-centered development approach to create resilient cities that are self-sufficient during both ordinary and extraordinary times. The goal is to enhance people's self-efficacy and emotional well-being while designing urban areas that allow residents to live safely and happily under diverse conditions. To achieve sustainability, the following three requirements have been defined, aligning with the urban functioning goals discussed in Section 2.1:

(1) Formation of a Walkable Urban Cluster and Access to the Nexus:

Urban clusters should integrate essential services and amenities within a walkable distance, fostering a nexus that includes culture, art, and exchange alongside conventional necessities like water, food, and energy. These elements, collectively termed the "new nexus," play a vital role in shaping self-efficacy. Ue (2018) demonstrated that prolonged engagement in artistic activities correlates with higher general self-efficacy, underscoring the importance of cultural components in urban design.

(2) Construction of a Multi-Modal Network Connecting Clusters:

A robust multi-modal network should support the movement of people, goods, and information while facilitating risk management and communication. This network integrates cyberspace with physical space, enabling flexible adaptation to unpredictable situations. It also connects spatial and contextual elements, including nature, history, and culture, creating a and responsive urban framework.

(3) Development of Reversible Infrastructure Systems:

Urban infrastructure must be designed to operate effectively in both ordinary and extraordinary times, emphasizing disaster risk mitigation and preparation. Such systems enhance resilience and adaptability during emergencies while supporting daily urban life.

The proposed community-centered development represents a spatial adaptation of Camagni's "local milieu" concept, as discussed in section 2.2.1, fostering the creation of clusters for urban living and innovation in lifestyles through interconnected multi-modal networks. This urban milieu approach addresses not only the attractiveness of urban areas as hubs for creativity and innovation but also their functionality as resilient, livable spaces. As Hooijen (2021) highlighted, growth-oriented paradigms—common in spatial planning—may no longer suffice, suggesting the need for alternative strategies focused on sustainability and inclusivity.

In dense urban environments like city centers, leveraging underutilized void spaces, as discussed in Section 2.2.2, can address the lack of social nexuses required for survival during extraordinary times. **Figures 2.4 and 2.5** illustrate the spatial and network relationships that underpin the proposed design concept. Urban clusters, as depicted, are walkable units equipped with diverse transport modes to support daily mobility. Orbital public transport systems, such as rail and LRT, connect these clusters while allowing restricted inter-cluster movement during outbreaks to comply with lockdown measures. The left diagram in **Figure 2.5** shows a self-sustaining and segmented urban structure designed to enhance convenience in normal times while remaining functional in emergencies.

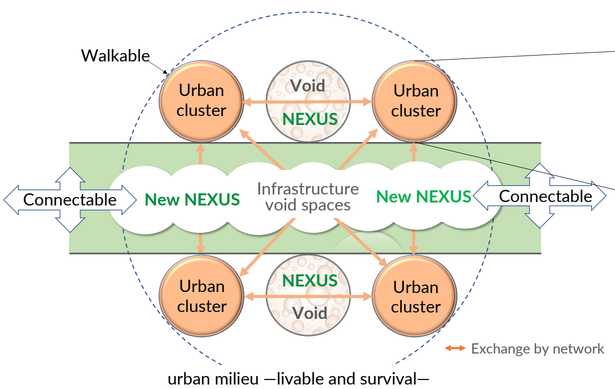

Figure 2.4 Image of new spatial design to foster urban milieu.

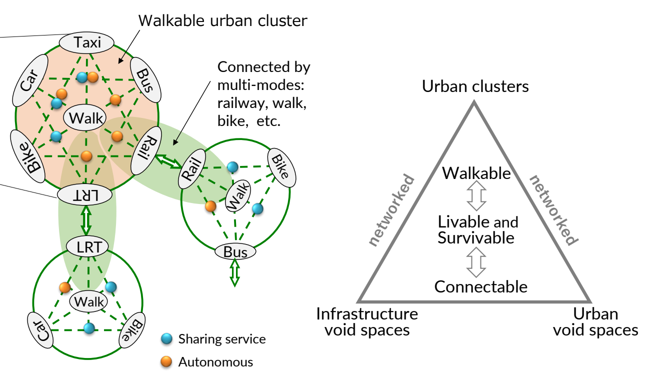

Figure 2.5 Networked urban clusters.

Figure 2.6 presents a conceptual framework for the proposed community-centered design, integrating the dimensions of information, time, space, and environment to achieve synergistic urban functions. Along the information and time axes, smart cities enable risk communication and dynamic policy interventions. Compact city principles are applied along the spatiotemporal axis, while creative city functions are positioned along the spatiotemporal axis. Together, these elements allow step-by-step risk management through assessment/response and preparation/mitigation, offering a cohesive and adaptable strategy for building resilient, sustainable cities.

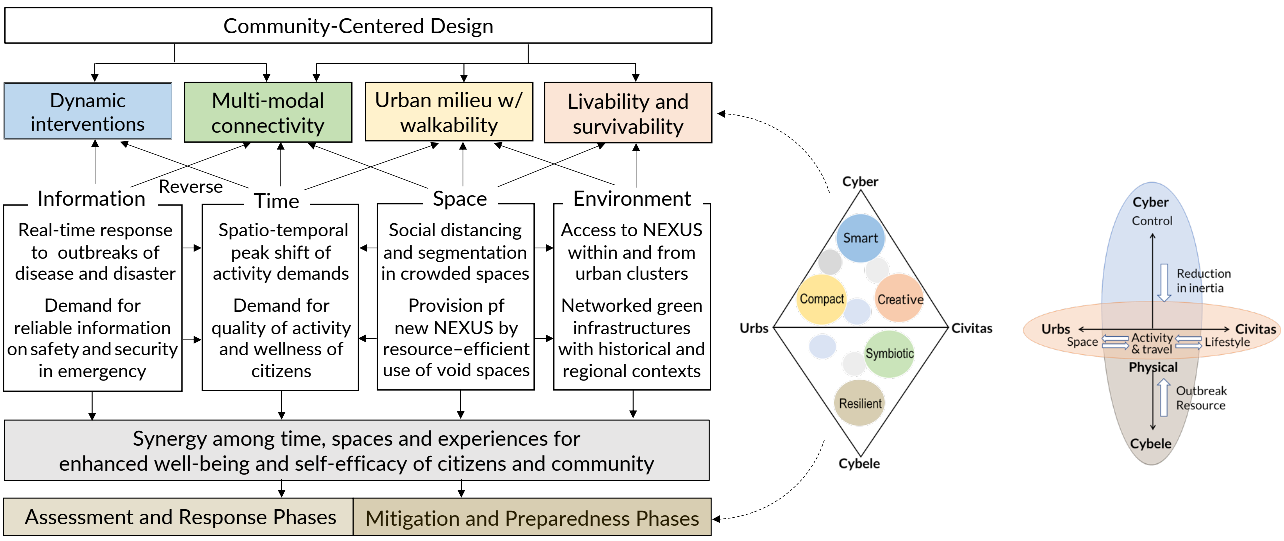

Figure 2.6 Conceptual framework of new community-centered design.

In the following section, the potential for creating resource-efficient and decentralized public spaces, as suggested by Afrin et al. (2021), is examined within the context of Japan's transportation infrastructure and urban public transport strategies.

The studied cases examine the continuous void spaces under elevated railways, created by multi-level railway crossing projects associated with urban redevelopment. These spaces represent valuable yet underutilized areas in dense urban settings with high feasibility for adaptive planning. Beyond their continuity, the symbolic value of elevated structures and their straightforward flow lines offer opportunities to enhance and revitalize urban areas along railway lines. Historically perceived as "walls" dividing cities, elevated railways have the potential to transform into vibrant urban hubs. These continuous void spaces between railway stations can attract people, not vehicles, to the heart of the city, creating spaces for walking, interacting with nature, shopping, dining, and leisure. Such spaces are envisioned as healthy, resting environments with pedestrian-friendly designs that serve as axes for livable and sustainable urban areas.

2.4 Case Studies: Utilizing Void Spaces in Rail Infrastructure

In Japan, the urban policy initiative known as the “Compact Plus Network” aims to consolidate urban functions and residences around transit hubs, such as stations and bus stops, while strengthening public transportation networks to create an integrated urban structure. To support this vision, many local municipalities have developed location optimization plans. These plans are bolstered by subsidies and tax incentives, which encourage the concentration of urban functions and residential developments in designated areas. However, challenges remain in realizing this policy, particularly regarding the economic feasibility of acquiring and developing new land and buildings within the guidance areas.

The pandemic has further underscored concerns about infection risks associated with dense urban centers and crowded public transportation during commutes. This has prompted a rethinking of the “compact” urban concept, shifting the focus beyond spatial density to also consider the time axis. Emphasis is now placed on creating “dense” activities and experiences within high-quality, timely, and spatially optimized environments—referred to as “cozy places”—that enhance both functionality and livability.

To illustrate how the new community-centered design can be realized under the “new normal,” the following subsections examine examples of transportation machizukuri initiatives implemented in Japan. These case studies highlight collaborative partnerships among various stakeholders and showcase best practices in achieving 15-minute and 20-minute cities. Specifically, the examples focus on the utilization of spaces under elevated railway stations as hubs for vibrant activities and enriched experiences. By emphasizing spatial continuity in the areas surrounding railway stations, these cases demonstrate practical applications of the “new nexus” concept proposed in this study.

2.4.1 Sakumachi Shopping Street: Urban Milieu with Walkability and Livability

The Meitetsu Seto Line, operated by Nagoya Railroad Co. Ltd. (Meitetsu), is Japan’s third-largest railway operator, with a total network length of 444.2 km. The 20.6-km Seto Line connects Sakaemachi Station in Nagoya City’s central Sakae area to Owari Seto Station in Seto City, a commuter town for Nagoya. The railway elevation project was completed in 1990.

Shimizu Station and Amagasaka Station, where the Sakumachi shopping street is located, became unmanned in 2006. With no public station plazas developed and accessibility limited to walking and cycling, the commercial value of the area around and between these stations remained low. Additionally, the space beneath the elevated railway was underutilized for years, primarily serving as parking lots (Sakumachi Shopping Street, 2021).

Around 2010, Meitetsu shifted its development strategy from a traditional profit-driven focus to one centered on community development. This pivot led to plans for utilizing the under-elevated spaces, particularly in areas like Sakumachi, a high-class residential zone with the strongest branding potential in Nagoya City. Recognizing this area's cultural and commercial value was a key factor in formulating the development plan.

Initially, Meitetsu did not collaborate with the local government. However, under its new strategy of contributing to community development, the company began engaging with government partners and involving local residents through briefing sessions. By listening to residents' opinions and fostering relationships beyond traditional stakeholder roles, Meitetsu established a co-creative framework that integrated the government as a partner. This approach not only enhanced the area's brand value but also strengthened the company's regional role and corporate image. A key objective of the development was to attract new railway users to the under-elevated shopping district.

Collaboration with community-based design offices also played a significant role in reimagining the continuous infrastructure space. This partnership enabled innovative approaches beyond conventional railway operator strategies, transforming the area into a livable space with functions essential for daily life. Initially, some residents expressed concerns about losing the openness of the space. However, after the shopping district opened, opinions shifted as locals appreciated the vibrancy brought to the neighborhood.

Sakumachi exemplifies the realization of mixed land use by revitalizing void spaces in residential areas. It embodies the concept of a "short way city," redirecting foot traffic from Nagoya's city center to facilities near local stations. As residents experience and share the charm of the revitalized space, it garners wider recognition as a local attraction. This dynamic transformation positions the area as a "milieu" that fosters connection and shared identity. Additionally, the district's cherry blossom-lined sidewalks offer seasonal appeal, attracting crowds during the cherry blossom season. Sakumachi demonstrates how leveraging existing natural and cultural assets can enhance regional branding and create new local attractions.

2.4.2 Inter-Station Urban Development: Fostering Connectivity in Urban Milieus

Onojo City, located in Fukuoka Prefecture and developed as a commuter town for Fukuoka City, leveraged the newly created continuous space from the elevated railway project of Nishi-Nippon Railroad Co. Ltd. (Nishitetsu) on the Tenjin Omuta Line. From the outset, utilizing the continuous railway infrastructure space was designated as a key policy, marking a pioneering effort to formulate a comprehensive utilization plan across all sections, including commercial areas (Onojo City, 2020).

The city established five guiding concepts for its planning policy: Nishitetsu's community, wellness, and mobility themes, complemented by a focus on communication and culture. By integrating the elevated railway infrastructure with broader urban development, the city aimed to create a central, memorable space that would serve as a new symbol for the community, fostering population growth along the railway line.

As depicted in **Figure 2.7**, the plan includes a plaza and pedestrian space under and around the elevated railway. Sidewalks along the elevated frontage road have been integrated to unify blocks along the railway line. This design aims to reduce overall activity and movement time, create more opportunities for relaxation, shopping, and social interaction, and attract a larger population to the railway-adjacent areas. Additionally, the elevated space and frontage road are seamlessly connected, maximizing the continuity of the railway and enhancing the area's usability and appeal.

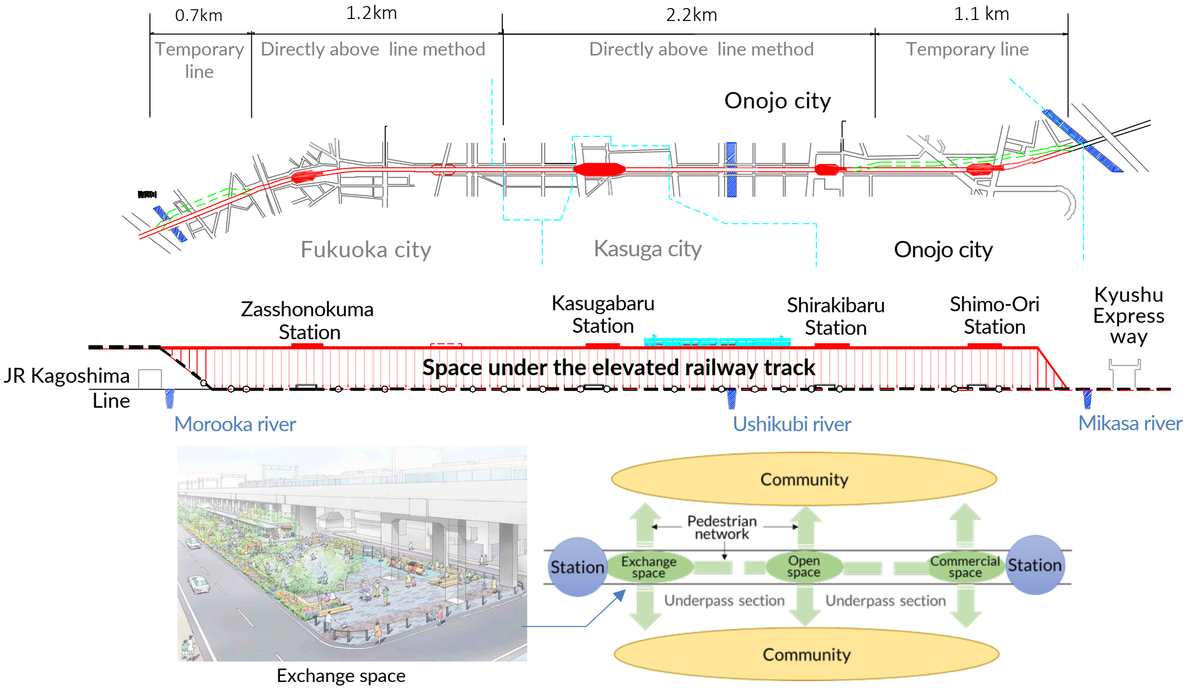

Figure 2.7 Outline of Onojo "inter-station" urban development.

This plan to establish a continuous walking environment aligns seamlessly with Onojo City's comprehensive urban development strategy. The space beneath the elevated railway forms part of the Park Line, which connects the Mizuki Castle Ruins, a significant historical landmark in the city. By integrating route buses, community buses, and railways, the city aims to diversify mobility options, and enhance the functionality of the continuous infrastructure space. Additionally, a cross-sectional walking network links the continuous infrastructure exchange plaza with urban areas along the railway line. This network connects the infrastructure space to new urban hubs, community exchange points, and historical heritage sites, creating a ripple effect that enhances the value of the city.

Beyond mobility, the city incorporates community, wellness, and a new nexus of culture, art, and exchange into the use of continuous infrastructure space. To meet diverse transportation needs, the city is exploring next-generation mobility solutions, such as integrating Mobility as a Service (MaaS), reorganizing community bus routes, expanding bicycle-sharing programs, and enhancing bicycle parking facilities. By increasing mobility options, strengthening the connectivity between transport modes, and improving walkability, the plan addresses a wide range of transport demands (Ue, 2018).

A standout feature of Onojo City's plan is its ability to support an autonomous, self-sustaining, and segmented urban structure that remains functional during emergencies. In the event of an outbreak or disaster, movement beyond walkable clusters can be restricted by halting connections between railway stations. At the same time, the plan ensures that walking and low-speed mobility within the elevated railway space can continue. This approach maintains critical functions, such as the transportation of water and food (i.e., nexus), human interaction, and cultural activities (i.e., new nexus), even under extraordinary circumstances.

In comparison, Meitetsu's Sakumachi project focused primarily on creating a livable space (Onojo City, 2020), as shown in **Figure 2.8 and Figure 2.9**. In contrast, Onojo City's initiative integrates walkable and connectable elements into its spatial design, fostering collaboration among stakeholders from the early planning stages. While the commercial use of elevated railway spaces initially faced opposition in the Sakumachi project, emphasizing well-being and visualizing the plan led to a significant shift in residents' perceptions. Learning from this experience, Onojo City has prioritized "preliminary empathy formation" with stakeholders, including citizens.

Furthermore, railway operators in Onojo recognize the importance of regional revitalization along the railway line and its impact on increasing ridership. The city's focus on enhancing the area's appeal through collaboration among municipalities, citizens, and businesses has established a strong win-win relationship. This holistic approach ensures the long-term success of urban redevelopment efforts around railway terminals and other critical areas.

Meitetsu Seto Line: SAKUMACHI

	Category of use	No. of places
Livability	Entertainment	1
	Sports	1
	Beauty	2
	Culture	1
	Grocery	4
	Eating and drinking	7
	Clothing	1
	Work spaces	1
	Education	2
	Total	20

Nishitetsu - Omuta Line : Onojo City

	Category of use	Quantity and scale
Livability	Square	4 places 3,770㎡
	Multipurpose facility	3 places 1,660㎡
Walkability	Promenade	800m, 3,000㎡
	Walking shelter	2 places 2,000m
Connectability	Bicycle parking lot	4 places 2,714 vehs
	Station square	1place 2,700㎡
	Bus shelter	1place 580㎡

Survivability	NEXUS, Agriculture Small delivery depot	To be Secured in the future

Figure 2.8 Prioritized functions highlighted in two cases of community-centered design.

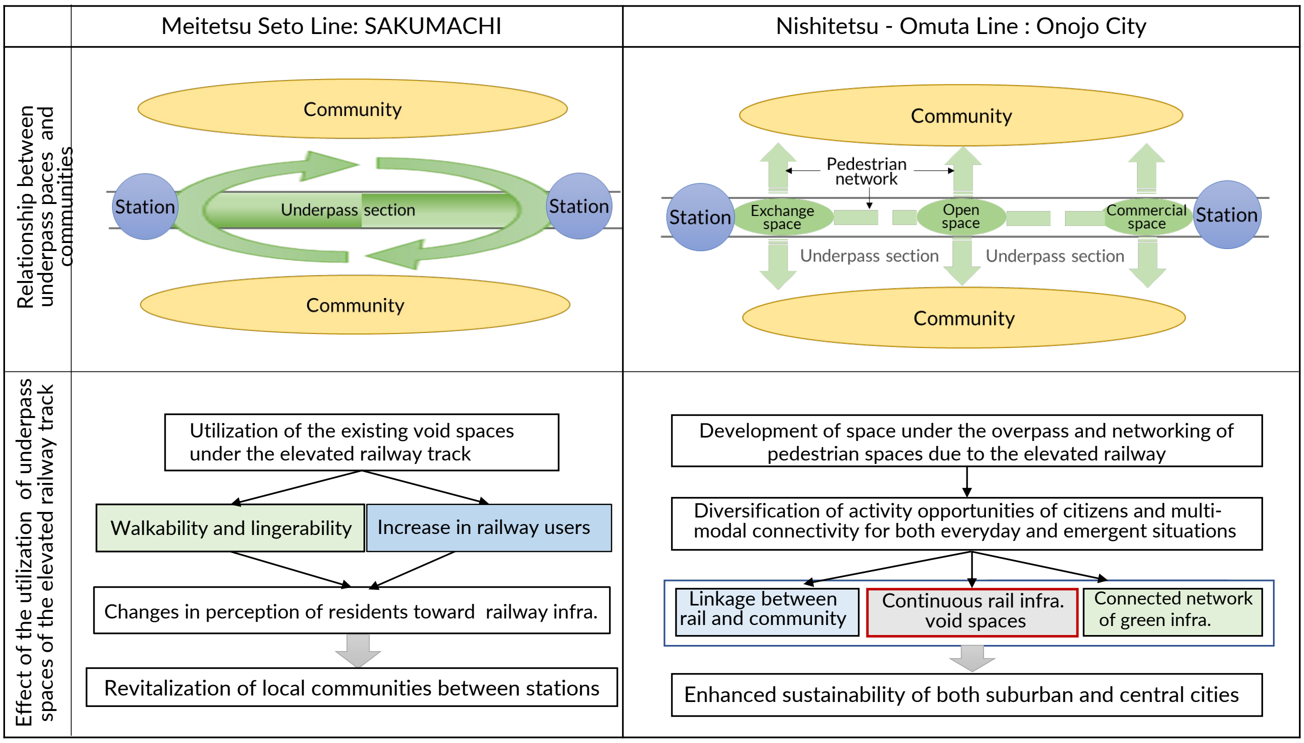

Figure 2.9 Comparison of two pioneering cases.

2.5 Conclusions

To achieve a sustainable city in the new normal, there is an increasing need for urban systems that are both independent and self-sufficient during emergencies while enhancing well-being during normal times. This paper proposed a community-centered design concept to fulfill this purpose by fostering collaboration among various stakeholders. The proposed community-centered design emphasizes achieving three core urban functions: (1) balancing the protection of individual lives with maintaining urban functionality and societal well-being, (2) aligning global goals such as the SDGs and carbon neutrality with regional development goals rooted in historical and cultural contexts, and (3) harmonizing extraordinary and everyday systems to address unpredictable outbreaks effectively.

A key aspect of this design lies in securing essential "nexuses," often overlooked in daily life, and implementing resource-efficient strategies to support these nexuses. This study highlighted the potential of utilizing void spaces to construct a networked urban milieu and proposed strategies to reschedule limited transport resources, thereby maximizing users' time wealth and encouraging public transport ridership. By addressing these issues, this chapter underlined the importance of creating reversible systems for ordinary and extraordinary times, fostering synergies across information, time, space, and environment, and cultivating compassion among stakeholders and residents. The study also proposed urban strategies that balance density and livability through multi-layered, multi-modal mobility, particularly in continuous infrastructure such as railways that connect city clusters.

Two case studies demonstrated practical applications of this approach. In the case of Sakumachi, previously underutilized space beneath elevated railways was successfully transformed for commercial purposes. By emphasizing collaborative partnerships with local municipalities and valuing residents' input, the project fostered empathy and recognition of the redesigned space as a local attraction. The new design intensified recreational and cultural functions, confirming the spatial dynamics of the milieu. In Onojo City, the project involved stakeholders from the planning stage, emphasizing "preliminary empathy formation" with citizens. By promoting walkable and connectable urban design, the initiative created an autonomous, self-sustaining, and segmented urban structure that could adapt to extraordinary circumstances. These cases illustrate how industry-government-private partnerships are already implementing community-centered designs, responding to new normal conditions.

This chapter proposed a meta-design framework for sustainable city development. The case studies elaborated how urban milieu forms a foundational fabric of urban spaces, influencing well-being by integrating social, cultural, and environmental elements that define the character and functionality of cities. It contributes to well-being by fostering environments where people feel connected, supported, and engaged with their surroundings.

The following chapters elaborate how three dimensions—Cyber, Urbs, and Civitas—play crucial roles in enhancing urban well-being by leveraging compassionate mobility system design method (**Figure 2.10**). Cyber leverages digital technologies to create smarter, more responsive urban environments that enhance the efficiency and comfort of urban mobility, providing residents with the tools they need to navigate and optimize their daily activities efficiently. Urbs focuses on the physical infrastructure, designing accessible and safe public spaces that encourage movement and interaction, improving health and social connections. Meanwhile, civitas enriches social well-being by enhancing community engagement and ensuring that policies and practices are inclusive, promoting legal and social frameworks that support community needs and enhance livability. Together, these dimensions work synergistically within the urban milieu to create cities that are not only functional and resilient but also nurturing and inclusive, ultimately elevating the overall quality of life for all residents.

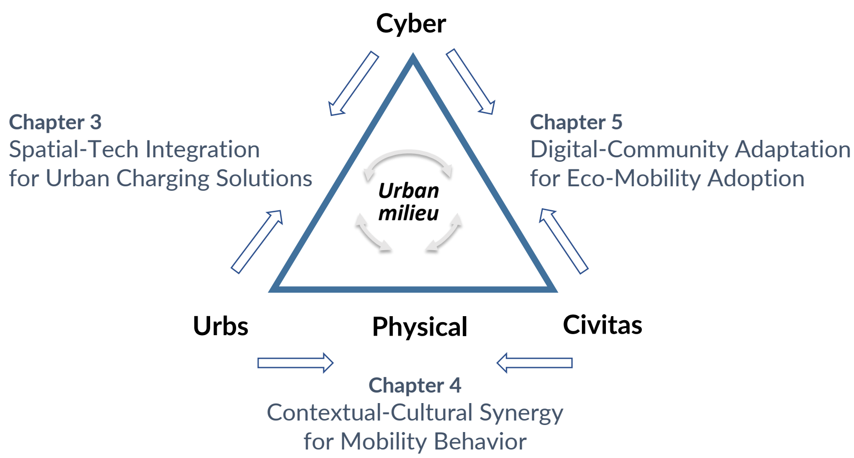

Figure 2.10 Study framework of the following chapters.

3 Assessing the Role of Spatial Cognition in User Attitudes and Travel Behaviors

Summary: This chapter explores the transformative role of advanced charging technology in urban mobility, specifically focusing on how it interacts with the Urbs dimension to enhance human spatial cognition.

Emerging mobility services are pivotal in improving accessibility, bridging connectivity gaps, and addressing last-mile challenges within public transport networks. These services are essential for developing seamless, multimodal networks that promote efficient, inclusive, and sustainable urban transport. Although often introduced to support sustainable urban development, in some cities, these services are still perceived as recreational rather than critical transport modes.

The research presented in this chapter delves deeper into the influence of spatial experiences on mobility travel behaviors, an area previously underexplored. It examines whether enhanced spatial knowledge, aided by advanced charging technology and shaped by the physical layout of cities, leads to improved spatial experiences. This, in turn, could satisfy users' functional/instrumental and experiential/hedonic values for mobility trips. The study also investigates how spatial knowledge affects travel behaviors, particularly focusing on trip chaining and vehicle charging patterns.

To assess road users' spatial knowledge, sketch maps were employed to record changes after three months of using battery-sharing electric two-wheelers. This mixed-methods approach, combining sketch maps, questionnaire surveys on attitudes, and panel data analysis of activity-travel patterns, provided comprehensive insights.

The findings reveal that spatial experiences significantly influence perceived values and subsequent travel behaviors. Enhanced spatial knowledge not only leads to greater satisfaction with mobility travels but also facilitates more efficient use of urban transport resources. An interaction effect between cognitive distance and cognitive direction was identified, which notably impacts users' satisfaction with the driving range and charging logistics of electric vehicles. These results underscore the critical importance of integrating spatial knowledge in optimizing mobility experiences and promoting the adoption of sustainable transport solutions.

This chapter is a version of the following publication: Chou, C. C., Yoh, K., Hirokawa, S., & Doi, K. (2023). Co-evolution of Smart Small Vehicles and Human Spatial Experiences: Case Study on Battery-Sharing Electric Two-Wheelers Experiment. Sustainability, 15(20), 15171.

3.1 Introduction

Recent advancements in energy-charging technologies have facilitated the emergence of small electric vehicles (SEVs). SEVs function similarly to active modes of transport by fostering a stronger connection between travelers and their environment while promoting social and cultural cohesion (City of Lincoln, 2023). Simultaneously, they offer the motorized flexibility required for efficient spatial exploration. Research on user adoption of new mobility services has primarily focused on functional/instrumental and experiential/hedonic values (Schuitema et al., 2013; Putri et al., 2021). In some developed urban contexts, SEVs are perceived more as a source of entertainment than as a practical transportation mode (Kopplin et al., 2021). While experiential and hedonic values are well-documented influences on SEV adoption (Curtale & Liao, 2020), the specific role of spatial experiences in shaping urban travel behaviors remains insufficiently explored.

Spatial abilities, such as navigation and wayfinding, are particularly critical SEV users, especially with the introduction of battery-swapping solutions aimed at addressing charging limitations and extending EV range (Finke et al., 2022; Saur Energy, 2022). The adoption of battery-sharing mechanisms is anticipated to reshape urban travel patterns for EV users, closely linking their behaviors to the cognitive urban form and charging demands. Spatial cognition influences SEV users' behaviors, including acquiring spatial knowledge, planning routes, and perceiving distances to manage residual power effectively before reaching the next charging point. However, concerns about running out of power may restrict users' travel range, even as SEVs enhance mobility options. While technologies like GPS have simplified city navigation, cognitive maps remain essential for predicting access to potential opportunities and making travel decisions (Mondschein et al., 2006). In essence, individuals' choices to travel or stay are shaped by their perceived distances to destinations (Cadwallader, 1976).

Despite limited discussion in existing literature, this study posits that SEV users perceive their environment and behave differently compared to users of conventional private transportation modes, such as car drivers, cyclists, and walkers. Active-mode travelers, such as cyclists and pedestrians, experience their environment more directly due to their exposure to it, unlike car drivers, whose sensory engagement with the surroundings is more restricted. This study aims to empirically investigate the role of spatial experiences in SEV users' urban travel patterns. Specifically, it examines how traveling by SEV influences users' spatial knowledge, how varying levels of spatial knowledge impact their satisfaction with mobility experiences, and how spatial knowledge shapes their urban travel behaviors.

To address this research gap, the study provides a theoretical framework focusing on (1) theories of spatial knowledge acquisition in large-scale environments, (2) the influence of spatial experience on urban travel behaviors, and (3) methodologies for investigating cognitive maps. Insights derived from the literature inform the study's methodology, which involves analyzing road users' spatial knowledge, examining user attitudes, and exploring travel patterns. Data were collected from participants in a pilot project using battery-sharing electric two-wheelers (BSET) in Osaka, Japan, to provide empirical evidence for the study's hypotheses.

3.2 Theorical Background

3.2.1 Spatial Knowledge Acquisition

Cognitive mapping is a critical aspect of spatial knowledge acquisition, encompassing the mental processes through which individuals gather, store, recall, and manipulate information about the features and relative locations within their environment (Downs & Stea, 2017). As individuals interact with their surroundings, they develop spatial knowledge by recognizing relationships and attributes within the environment (Lynch, 1960). Research on spatial knowledge acquisition has been extensive, with several comprehensive reviews addressing this topic (Hart & Moore, 1973; Evans, 1980; Ahmadpoor & Shahab, 2019).

Prior studies have delved into how individuals remember and mentally represent medium- and large-scale environments, such as neighborhoods and cities (Palmer, 1978; Appleyard, 1969; 1970; Siegel & White, 1975; Moore, 1979). Lynch's seminal work identified five key elements—nodes, paths, districts, landmarks, and edges—that shape cognitive maps, offering a foundational framework for understanding how people mentally structure urban spaces (Lynch, 1960). Appleyard further investigated how social meanings influence cognitive representations of neighborhoods and cities, revealing that visibility, personal use, and the perceived importance of physical characteristics significantly shape individuals' environmental perceptions (Appleyard, 1969; 1970). He also emphasized the symbolic aspects of the environment, asserting that symbolism and meaning are central to human experiences in urban contexts (Appleyard, 1979a; 1979b). Building on these ideas, Moore (1979) highlighted developmental changes in how individuals perceive large-scale environments, noting a progression from social and physical understandings to more abstract, symbolic interpretations. Inspired by Appleyard's communications model of environmental action (Appleyard, 1979a), this study integrates the concepts of cognitive affordance and cognitive mapping to explore dynamic cognitive processes in situational contexts.

Physical environments exert significant influence on human behavior through the concept of affordance, originally introduced by perception psychologist James J. Gibson (1966; 1979). Affordance describes the opportunities and possibilities an environment provides to individuals. Lazarus (1991) expanded on this idea, linking affordances to an individual's needs and emphasizing the preconscious appraisal of environmental opportunities (Lazarus, 1991). In architecture, affordance serves as a framework for understanding the interaction between a space's design and its occupants, particularly regarding form and functionality (Maier, Fadel, & Battisto, 2009). Cognitive affordance, a subset of this concept, plays a pivotal role in interaction design by facilitating thinking and learning processes, especially for users with limited prior experience (Hartson, 2003).

This framework underscores the interplay between the physical environment and cognitive processes, providing a foundation for examining how individuals acquire and utilize spatial knowledge.

Affordance and Cognitive Mapping

Marcus, Giusti, and Barthel (2016) expanded the concept of affordance into the realm of urban design, highlighting its significance for sustainable urbanism and the dynamic interaction between individuals and their situated cognition. They proposed that the everyday environment functions as an interface through which individuals learn and develop skills as their personal abilities interact with situational opportunities, or affordances. This interaction shapes the way people perceive and utilize their surroundings.

In the dynamic relationship between individuals and the built environment, designed features may carry different social meanings depending on the user. For instance, in road environments, road users progressively develop spatial abilities that enable them to identify and actualize the affordances of their surroundings through everyday experiences. These affordances may arise from various elements, such as road space (e.g., traffic conditions, infrastructure design), surrounding architectural features, and natural landscapes. This continuous interaction fosters an evolving understanding of the environment, enabling users to navigate and respond effectively to its potential opportunities.

Spatial Learning

The process of acquiring spatial knowledge, referred to as spatial learning, progresses through three distinct stages: landmark, route, and survey (Siegel & White, 1975; Stern & Leiser, 1988). Landmarks are prominent features in the environment that serve as reference points, providing basic location information and forming the foundation of cognitive maps. Route knowledge enables individuals to connect locations along specific travel paths but does not provide a comprehensive understanding of the overall spatial organization. Survey knowledge represents the highest level of spatial learning, where individuals gain a holistic understanding of the environment, including the relative directions and distances between multiple locations.

Spatial experiences, especially within an individual's activity space, significantly influence the acquisition of spatial knowledge. According to the anchor-point theory, people develop the most extensive knowledge of areas surrounding their homes and workplaces (Golledge, 1978). Anchor points play an active role in organizing spatial relations within cognitive maps, serving as hubs for integrating spatial information (Couclelis & Golledge, 1987).

3.2.2 Spatial Experience and Urban Travels

The relationship between spatial experience and transport users' attitudes has received limited attention in the literature. However, insights from architectural research highlight that the design of space, particularly in small-scale environments, conveys distinct social symbols that influence spatial behaviors (Vilnai-Yavetz & Rafaeli, 2021; Wineman & Peponis, 2010). In large-scale environments, studies have explored how elements like visual design and vegetation impact spatial memory (Samarasekara; Fukahori, & Kubota, 2009). Research has also emphasized the connection between road users' perceptions of the built environment and their travel motivations. For example, Mirzaei et al. (2018) found that built environment characteristics significantly influenced both utilitarian and hedonic walking behaviors, with pedestrians' perceived value shaping their mobility choices.

In the context of small electric vehicles (SEVs), which share similarities with active transport modes, understanding hedonic motivations is essential, as they differ substantially from motivations associated with car travel. SEV users' instrumental attitudes, such as improved spatial knowledge, can also play a critical role in navigating charging spots and managing battery power efficiently by accurately perceiving distances.

Trip planning relies on cognitive maps of large-scale environments, which facilitate navigation and movement, enabling trip plans that minimize travel time or leverage shortcuts and alternative routes (Garling, Book, & Lindberg, 1984). Research has shown that spatial knowledge influences various aspects of trip planning, including trip purposes, route complexity, and destination diversity. For example, cyclists' spatial learning stabilizes after repeated trips, with their activity patterns and route dynamics evolving over time (Zomer, 2021). Comparative studies among car drivers, cyclists, and walkers reveal that differences in spatial knowledge influence trip-chaining behaviors and daily activity patterns. Those with higher mobility and spatial knowledge are better equipped to plan and execute complex trips involving multiple destinations (Schneider et al., 2021; 2022).

Despite these findings, trip-chaining behaviors with SEVs remain underexplored. Investigating how SEV users engage in trip chaining, including the sequence and purpose of multiple stops, is crucial for understanding their travel behaviors. Additionally, constraints like the residual power of EV batteries impact the duration and sequence of stops, posing unique challenges. Therefore, studying the interaction between users' spatial cognition and EV-related constraints is vital for comprehending SEV users' activity-travel patterns and developing better support systems for their mobility needs.

3.2.3 Techniques for Investigating Cognitive Maps

Various methods have been employed to study human spatial knowledge, ranging from traditional approaches like sketch maps, route descriptions, and distance estimates to advanced techniques in cognitive psychology (Foreman & Gillett, 1997; Els et l., 2006). Among these, multidimensional scaling (MDS) and Pathfinder networks have been extensively used to quantify similarity judgments (Kruskal & Wish, 1978; Shoben, 1983), with MDS being particularly prominent for evaluating distance and direction judgments (Regian & Yadrick, 1994; Waller & Haun, 2003).

Studies comparing MDS-derived maps to sketch maps have demonstrated that both approaches can produce accurate representations of spatial relationships in familiar environments (MacKay, 1976; Furlough & Gillan, 2021). Sketch maps offer a flexible and intuitive means for respondents to express their unique perspectives and spatial knowledge, including landmarks, routes, and points of interest. On the other hand, MDS generates coordinate spaces from distance data by assigning a set of reference landmarks to compare map accuracy across individuals. However, the social meanings ascribed to these landmarks can vary among individuals, potentially influencing the accuracy of MDS-derived maps (Appleyard, 1969; 1970).

Given these considerations, this study employs sketch maps to examine cognitive maps, as they allow for a more personalized representation of spatial knowledge. While sketch maps provide valuable insights, the study acknowledges the need for innovative methods to analyze and interpret them effectively for broader applications.

Relevant Methods to Analyze Sketch Maps

Lynch's (1960) key elements—nodes, paths, districts, landmarks, and edges—are foundational in studying cognitive maps and structuring large-scale spaces (Jonge, 1962). To accurately represent spatial properties in mental maps and enhance spatial layout recall, techniques have been developed for both qualitative and quantitative analysis of sketch maps (Golledge, 1977; Moore & Golledge, 1976).

Qualitative analyses focus on identifying clusters of features, interpreting the meanings of depicted symbols, and examining whether participants share common meanings. Recent studies have explored relationships between socioeconomic status and map scales (Banerjee & Baer, 2013), the impact of transport modes and GPS on city images (Minaei, 2014), and the influence of location-based media (LBM) on spatial experiences (Iavarone & Hasgül, 2021). Quantitative analyses, on the other hand, use statistical methods to measure spatial patterns and relationships, such as calculating landmark distances, density, or clusters of similar features (Evans, Marrero, & Butler, 1981; Moore, 1973). However, a notable limitation is the variability in the amount of information respondents choose to include in sketch maps, making it challenging to compare quantitative data across individuals or time periods.

To address this limitation, this study aims to refine and expand quantitative indicators for evaluating sketch maps. Previous research has primarily assessed spatial ability in small-scale environments using measures like route distance accuracy and absolute angular errors between landmarks (Thorndyke & Hayes-Roth, 1982; Waller, Hunt, & Knapp, 1998). These evaluations typically rely on in-person surveys or indoor spatial tasks (Ishikawa & Zhou, 2020), focusing on distance and direction knowledge.

The lack of robust quantitative indicators for assessing individual spatial experiences in large-scale urban environments presents a significant research gap. This shortfall restricts broader applications and hampers understanding of how spatial cognition influences travelers' activity-travel patterns. To bridge this gap, the present study evaluates changes in individual spatial knowledge through a quantitative analysis of sketch maps illustrating respondents' everyday road environments. By applying refined indicators to urban imagery in these maps, the study examines how spatial experiences influence the attitudes and travel behaviors of micromobility users, with particular attention to activity-travel patterns and battery-swapping behaviors.

This research seeks to contribute to the understanding of the interaction between spatial cognition and urban travel, offering new insights into how SEV users' spatial experiences shape their travel decisions and usage patterns.

3.3 Materials and Methods

3.3.1 Research Questions

From the perspective of environmental affordances, individuals with enhanced spatial knowledge gain a more comprehensive understanding of their surroundings, enabling them to better identify and utilize available resources to meet their needs. This raises a key research question: does a deeper understanding of the environment result in a more fulfilling user experience by aligning with expectations and ultimately increasing satisfaction with mobility travel? To explore this, the study focuses on addressing the following questions:

(1) To what extent does spatial experience enhance spatial knowledge?

(2) To what extent does an improved spatial knowledge of distance and direction correlate with increased travel satisfaction?

(3) To what extent does an improved spatial knowledge of distance and direction correlate with efficient battery-swapping behaviors and complex travel patterns?

Figure 3.1 illustrates the conceptual framework of this study. Before utilizing a new mobility service, users rely on their pre-existing knowledge of the road space and urban environment. As they engage with the service, their spatial knowledge and travel activity patterns are anticipated to evolve through the accumulation of spatial and temporal mobility experiences.

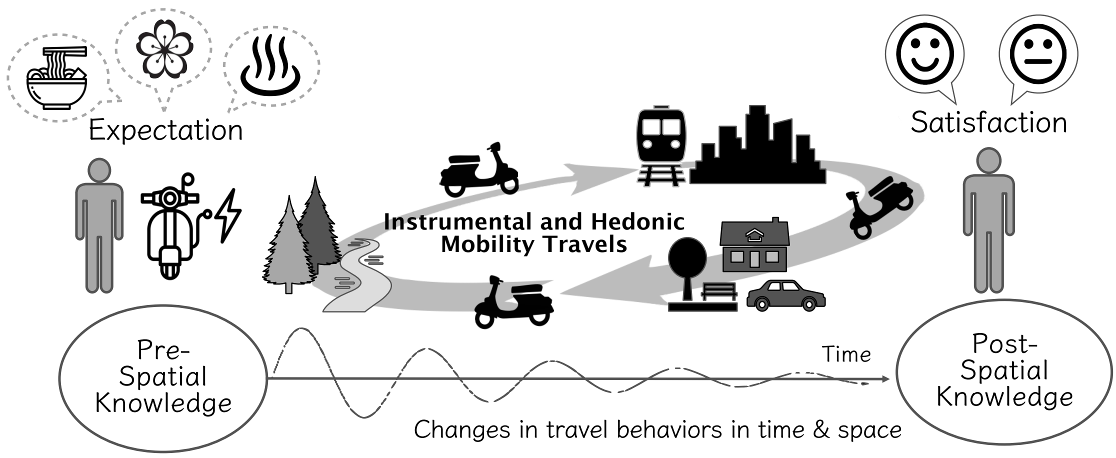

Figure 3.1 Conceptual idea of this study.

3.3.2 Analytical Framework

Figure 3.2 provides an overview of the analytical framework utilized in this study to address the research questions. A mixed-methods approach was adopted, integrating spatial knowledge analysis, user attitude exploration, and travel pattern analysis within the context of a new mobility service. The study gathered data from three primary sources: sketch maps to investigate spatial knowledge, questionnaire surveys to explore user attitudes, and vehicle tracking data to analyze travel patterns, with a specific emphasis on the trip-chaining behaviors of mobility users.

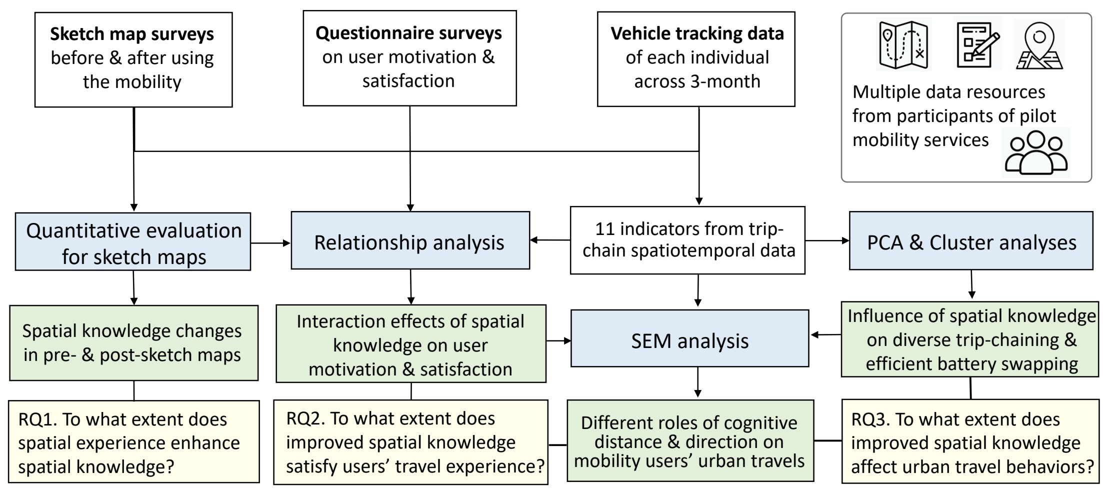

Figure 3.2 Analytical framework.

To address the first research question, a method was developed to quantify road users' spatial knowledge by evaluating their accuracy in perceiving relative distances and directions between landmarks. This involved analyzing changes in users' sketch maps before and after their participation in the pilot service. Spatial learning in this study accounted for on-road experiences prior to the pilot project, as well as travel distance, the number of trips, and the diversity of trip-chaining behaviors observed during mobility travels within the pilot project.

For the second research question, correlation analysis was initially applied to explore relationships between user expectations, satisfaction with the electric mobility system, and levels of spatial knowledge. A two-way ANOVA was further employed to compare group performance and examine the interaction effects between cognitive distance and cognitive direction on user attitudes.

To address the third research question, correlation analysis was used to examine the relationship between spatial knowledge and travel patterns, including indicators such as the total number of trip chains, travel distances, number of battery swaps, and residual power. Trip-chaining behaviors were analyzed by defining a trip chain as a sequence of trips beginning and ending at home. Principal component analysis (PCA) and cluster analysis were conducted to extract meaningful insights from the dataset. Specifically, cluster analysis utilized a finite mixture model (Melnykov & Maitra, 2010), a robust statistical framework for determining the number and validity of clusters (McLachlan, 2009).

Building on these analyses, structural equation modeling (SEM) was employed to provide a comprehensive examination of the direct and indirect effects of cognitive direction and cognitive distance on user attitudes and behaviors regarding service adoption. SEM enabled the investigation of complex relationships, offering insights beyond those obtained through correlation analysis alone.

3.3.3 Data Collection

Study Site and Context

Osaka Prefecture, situated on Japan's main island, has a population of approximately 8.79 million (as of August 1, 2022) and spans 1,905 square kilometers. As the central hub of the Keihanshin metropolitan area—the second-largest urban region in Japan after Greater Tokyo—Osaka boasts an extensive public transportation network. This network includes an advanced urban rail system, buses, monorails, and trams. Public transportation accounts for 26.3% of the modal share (24.2% railways, 2.1% buses), while motor vehicles contribute 26.9% (23.5% cars, 3.4% powered two-wheelers). Notably, walking and cycling are more common in Osaka compared to many other cities, with cycling at 22.5% and walking at 23.9% (Osaka Prefectural Government, 2012).

The “e-Yan Osaka” pilot project sought to explore the transformative potential of battery-swappable electric two-wheelers (BSET) in addressing challenges related to EV range, charging times, and recharging infrastructure. The project was a collaborative effort involving the Japan Automobile Manufacturers Association, four major Japanese motorcycle manufacturers, Osaka Prefecture, and Osaka University. Conducted over six phases, each lasting three months, the project spanned from September 27, 2020, to the end of March 2022. The authors, as core members of the initiative, were responsible for data collection, analysis, and evaluation.

Designed as a community-based mobility system, the pilot project provided electric two-wheelers to Osaka University students. Shared battery-swapping facilities were established at two university campuses and 10 convenience stores, allowing participants to swap batteries free of charge at 12 designated locations. The service primarily covered seven cities in the Hokusetsu region, located in northern Osaka Prefecture, a hilly area with unique mobility patterns. This region has a relatively lower public transportation modal share (23.4%) but higher shares for cycling (20.6%) and walking (26.5%). The higher-than-average modal share for powered two-wheelers (4.5%) suggests an increased awareness and acceptance of such mobility options in the region (Toyonaka City, 2019).

Participants

The pilot project spanned an extended period and was divided into six phases, with new participants recruited for each phase. From early July 2021 to the end of March 2022, a total of 53 participants joined the study. Data collection involved pre- and post-surveys, alongside vehicle tracking. The surveys included online questionnaires to capture user attitudes and sketch map exercises conducted using A3 map sheets. Online questionnaires were distributed via university emails, while the map sheets were provided in person. Surveys were administered on the first and last days of each phase. For participants who took part in multiple phases, only data from their initial phase were included in the analysis to prevent biases.

To ensure the reliability of the questionnaires and clarity of map instructions, pretest surveys and interviews were conducted twice. None of the participants had prior experience with battery-swappable electric two-wheelers (BSET), as the pilot project introduced the first system of its kind in Japan. Online seminars were organized to explain the project's goals, demonstrate the battery-swapping system, and detail the data collection process. After excluding incomplete responses, the valid sample size for analysis and discussion comprised 41 participants. Despite the limited sample size, the study employed a mixed-methods approach with multiple data sources to yield comprehensive insights.

Table 3.1 presents the participant profiles, revealing that 34.1% held two-wheeler licenses, while the remainder had car licenses permitting moped operation. Many participants had minimal riding experience: 29.3% reported no prior experience, and 31.7% rode less than once per month. To address this, mandatory training on safe riding practices was provided to all participants before they used the vehicles.

Table 3.1 Description of participants.

Characteristics	Category	Sample size	Percentage (%)
Gender	Male	36	87.8
	Female	5	12.2
Education	Undergraduate	25	61.0
	Master's student	12	29.3
	Doctoral student	4	9.8
Car driving license	Yes	38	92.7
	No	3	7.3
Driving frequency	3-5 times a week	3	7.3
	1-2 times a week	5	12.2
	1-4 times a month	17	41.5
	Less than 1 time a month	13	31.7
License for two-wheelers*	Moped (≤ 50 cc)	9	22.0
	Small (≤ 125 cc)	1	2.4
	General (≤ 400 cc)	5	12.2
	Large (> 400)	3	7.3
	No	27	65.9
Riding frequency	6-7 times a week	5	12.2
	3-5 times a week	5	12.2
	1-2 times a week	3	7.3
	1-4 time a month	3	7.3
	Less than 1 time a month	13	31.7
	No experience	12	29.3
Main way to commute to school*	Rail transit (railway or monorail)	4	9.8
	Bus	2	4.9
	Two-wheelers	5	12.2
	Electric bicycle	5	12.2
	Bicycle	30	73.2
	Walk	8	19.5

*Participants were asked multiple-choice questions.

3.3.4 Sketch Map Survey

Survey Design

The map sheet provided to participants was a white, landscape-oriented A3 paper, accompanied by the following instructions:

Suppose a friend asks you about the ways from your home to the station you often use and the university campus you belong to. Please draw the following (1) and (2) paths on one map. Please read carefully and follow instructions (i) to (iv).

(1) The road from your home to the station you use most (either a railway or monorail station).

(2) The road to the university campus, assuming you are heading from your home by a motorcycle or a car.

(i) Draw the map without consulting external resources, such as Google Maps.

(ii) Mark key intersections and landmarks along the routes (e.g., buildings or facilities) as accurately as possible.

(iii) Begin by placing your home (origin) and the two destinations (campus and station) on the map, ensuring they fit appropriately within the space of the sheet.

(iv) Allocate approximately 25 minutes to complete the task.

To assist respondents in comprehending the task, an example of a drawn map was included on the map sheet (**Figure 3.3**). This example served as a visual guide for participants to better understand the expectations for their submissions. To ensure consistency and facilitate meaningful comparisons, the instructions provided on the map sheets were identical for both the pre- and postsurveys.

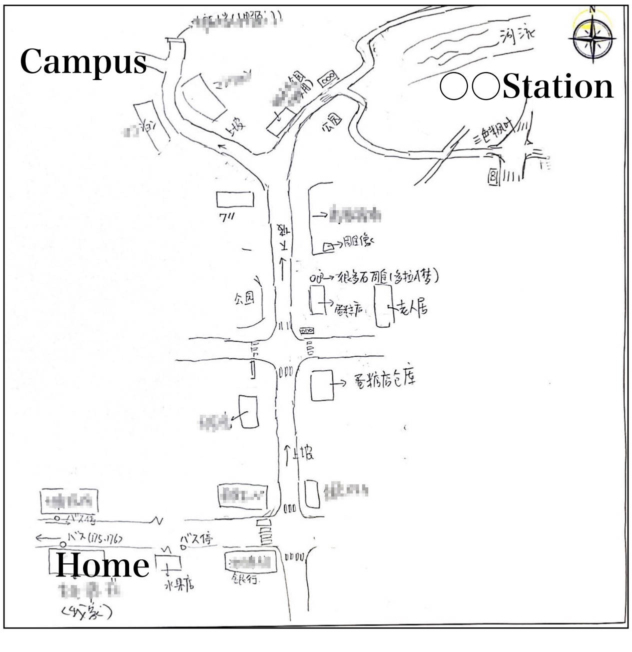

Figure 3.3 The given example on the survey sheet. The provided information was blurred to avoid including additional spatial details that might bias respondents.

Evaluation of Sketch Maps

To objectively quantify road users' perception of distance and direction, it is essential to establish common landmarks for participants to reference when drawing their maps. This study applied the anchor point theory (Golledge, 1978), selecting participants' home and work locations (i.e., the university campus in this case) as fixed reference points on the sketch maps. These anchor points served as a basis for consistent evaluation across individuals.

To illustrate the approach for analyzing the map data, **Figure 3.4** provides a comparison between painted map images created by participants and the corresponding real-world map data. This comparison highlights the differences and similarities in spatial representation, forming the foundation for further quantitative analysis.

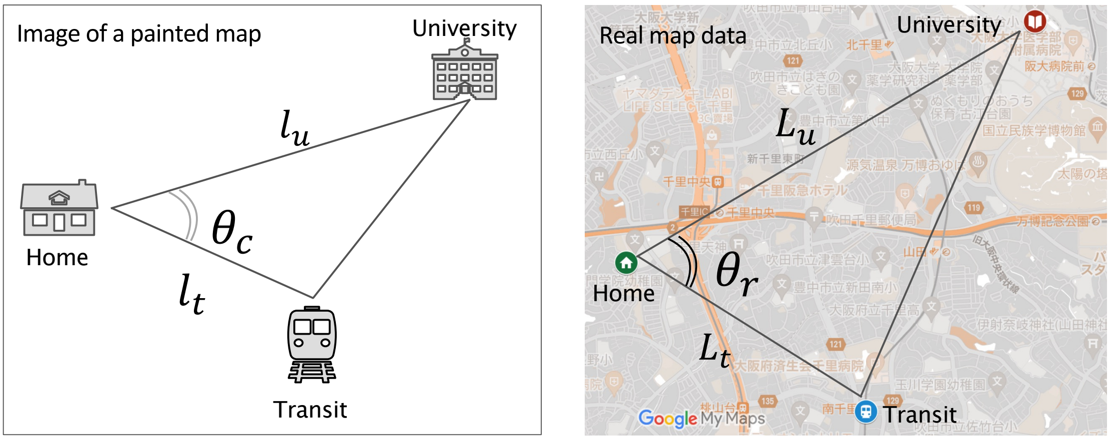

Figure 3.4 Illustration of the measures used to evaluate spatial abilities related to the sense of distances and directions between landmarks.

Setting the home, university, and transit station as common reference points, the accuracy of cognitive distance (ρ_{dist}) is calculated as follows:

$$\rho_{dist} = 1 - \frac{|(l_u/l_t - L_u/L_t)|}{L_u/L_t} \tag{4.1}$$

In this context, L_u represents the actual linear distance from a respondent's home to the university, while L_t denotes the linear distance from home to the transit station. The variables l_u and l_t correspond to the lengths of the lines connecting home–university and home–transit, respectively, as depicted in the respondents' sketch maps. The ratio l_u/l_t reflects the relative cognitive distance as represented in these maps. The accuracy of cognitive direction (θ_{dir}) was then assessed using angular error, which quantifies the discrepancy between the cognitive and actual relative directions among the designated reference points.

$$\theta_{dir} = 1 - \frac{|\theta_c - \theta_r|}{\theta_r} \cdot \frac{\theta_r}{180} = 1 - \frac{|\theta_c - \theta_r|}{180} \quad (4.2)$$

Here, θ_r represents the angle (in degrees) between the two lines connecting the respondent's home to the university and home to the transit station, based on Google Maps data. θ_c corresponds to the angle drawn on the sketch map. To address systematic errors caused by small values of θ_r, a correction factor $\theta_r/180$ was applied to the angular error ratio. This adjustment ensured the accuracy of the cognitive direction reflected the correctness of the sketched interior angle.

Dividing by 180 normalized the angular error, scaling it proportionally to the reference angle. Since the maximum possible angle between the three reference points (campus–home–transit) is 180 degrees, this normalization provided a relative measure of cognitive directional accuracy. These quantified metrics enabled a comparative analysis of changes in participants' spatial abilities and facilitated further exploration of the relationships between user attitudes and travel patterns.

3.3.5 Questionnaire Surveys

The surveys were administered in Japanese, utilizing everyday language to ensure clarity and minimize ambiguity. To measure responses, either 4-point or 5-point Likert scales were employed. Constructs reflecting various aspects of user values were developed based on the concept of value creation in marketing (Smith & Colgate, 2007). Functional/instrumental value evaluated the extent to which the new mobility system met travelers' practical goals, such as improving travel efficiency. Meanwhile, experiential/hedonic value focused on fostering positive emotional experiences, including heightened interest and enjoyment while driving.

The presurvey explored participants' motivations for joining the BSET pilot project through eight questions, evenly split between functional/instrumental (4 items) and experiential/hedonic (4 items) motivations. Rating scale statements were aligned with the item descriptions. For instance, functional/instrumental motivations were assessed with prompts such as: "*In terms of convenience and comfort for battery-swappable two-wheelers, please select the option that best applies to your expectations.*" These items typically included phrases like: "*Through riding E2W, I can…*" with response options ranging from 1 ("no expect") to 4 ("strongly expect"). Experiential/hedonic motivations were evaluated through statements like: "*Please tell us your motivations for participating in this experiment. Select the option that most closely matches your thoughts.*" Item descriptions typically included phrases like: "*I joined this experiment because it offers me opportunities to…*" with response options ranging from 1 ("disagree") to 4 ("strongly agree").

The postsurvey consisted of two sections. The first section assessed users' functional/instrumental and experiential/hedonic satisfaction, incorporating the corresponding items from the presurvey. The second section evaluated overall satisfaction with the BSET system (4 items), lifestyle changes (3 items), and specific concerns such as road safety (1 item) and battery charging issues (1 item). Detailed descriptions of the items and measurements are outlined in Section 4.2.1, which presents the descriptive statistics.

3.3.6 Vehicle Tracking Data

GPS trackers were installed in each vehicle to monitor participants' routes and record trip data, including origin and destination locations, travel time, travel distance, residual power, and battery identification numbers. This generated a comprehensive dataset for analysis. **Table 3.2** provides descriptive statistics summarizing these features across participants.

To investigate diverse activity-travel patterns, this study focused on analyzing trip-chaining behaviors. A total of 2,422 trip chains were generated by 40 participants, averaging 62 home-to-home trip chains per participant over a 3-month period. The cumulative travel distance reached 800.20 km, with the maximum number of trip chains recorded by a single user reaching 361—equivalent to over four home-to-home journeys per day. The average travel distance per trip chain was 12.91 km.

Participants swapped batteries an average of 22 times during the study period, with an average residual power of approximately 47%. The residual power ranged widely, from 22.7% to 77.3%, reflecting variations in participants' swapping behaviors and their concerns about managing battery charge levels. These findings underscore the diverse ways in which EV users approached trip planning and battery management.

Table 3.2 Descriptive statistics of individual travel patterns with the BSET.

	Total distances (km)	Trip chains	Swapping times	Residual power (%)
Mean	800.20	62.0	22.9	47.23
Min	63.4	7	3	22.7
Max	5512.0	361	70	77.3
S.D.	1065.16	72.03	15.30	11.39

Analysis of Trip-Chaining Behaviors

Trip-chaining behaviors were analyzed by defining a trip chain as a sequence of trips that begins and ends at home. Eleven indicators, adapted from Ohba and Kishimoto (2013), were estimated using geometric and temporal information for each trip. These indicators provided a detailed understanding of activity patterns and travel dynamics. To visualize these metrics, **Figure 3.5** presents a convex hull representing a home-to-home trip chain. (1) The number of vertices within the convex hull indicates the number of destinations, while (2) the area represents the range of travel. Additionally, (3) the total travel distance of a chain is determined by summing the travel distances of each trip.

The straight distance from home to the stop with the longest stay is defined as (4) the distance to the main destination. As shown in **Figure 3.6**, (5) the width based on the main destination, represented by the cross line with the largest length from the straight line connecting home and the main destination, indicates the degree of freedom for stopovers. Similarly, using the indicator of (6) distance to the farthest destination, the width is obtained based on the farthest destination, which reflects the extended range of activity patterns.

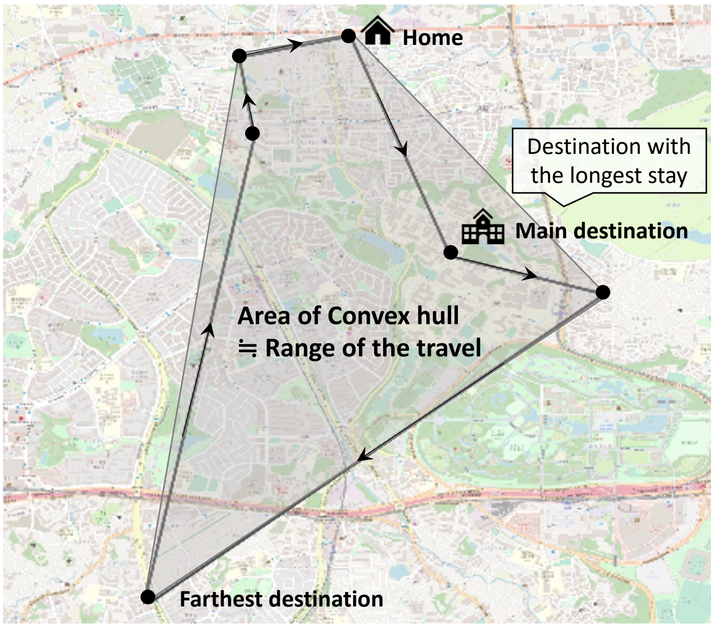

Figure 3.5 Illustration of a convex full formed by a home-to-home trip chain.

Furthermore, we generated (8) the ratio of the width to the distance of the main destination and (9) the ratio of the width to the distance of the farthest destination. These ratios present the “slenderness” of trip chaining. A small ratio indicate that the locations of stops are likely to be close to the routes from home to the main/farthest destination, showing a tendency to travel along the same axis and lower freedom of movement. Conversely, a larger ratio means a higher tendency to travel across the city. In addition to spatial indicators, the remaining indicators captured the temporal features of a trip chain, including (10) the staying duration at the main destination and (11) the sub-destination.

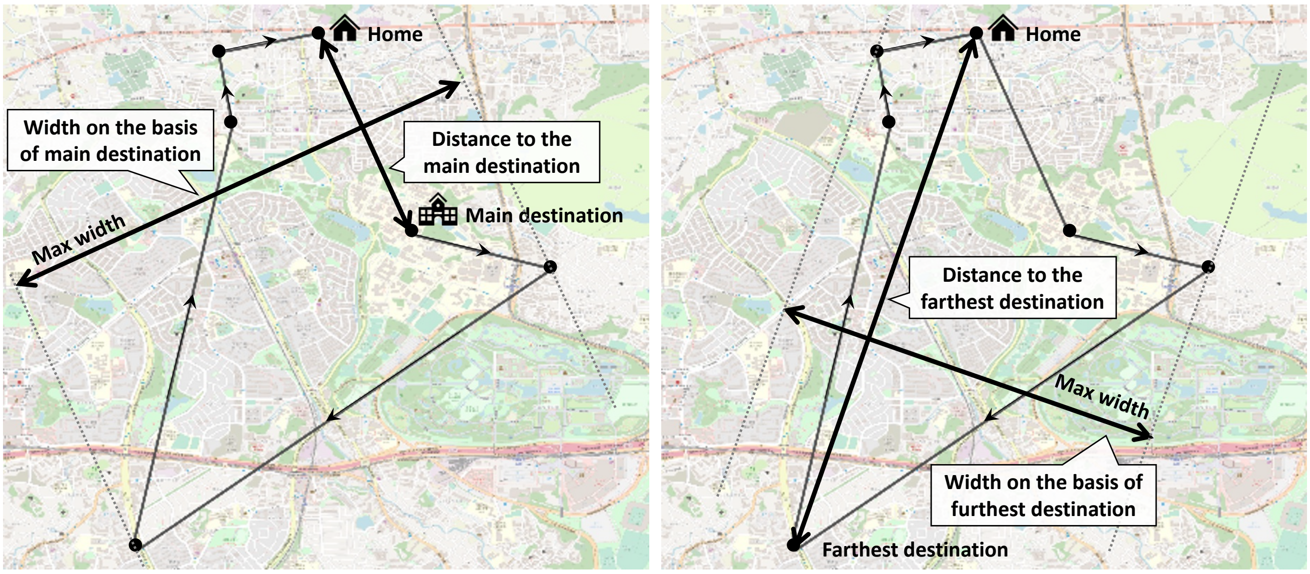

Figure 3.6 Illustration to give definitions of proposed indicators concerning the main destination (the left side of the figure) and the farthest destination (right side).

3.4 Results

3.4.1 Changes in Sketch Maps

Figures 3.7–3.10 present examples of pre- and post-sketch maps, illustrating the designed evaluation measures. Auxiliary lines connecting the reference points (home, university, and transit) are included to aid in analysis. These examples compare the pre- and post-sketch maps to assess changes in cognitive distance and direction accuracy. The designed measures evaluate how closely the drawn maps align with actual map data. To ensure privacy, specific spatial details, such as the exact locations of respondents' homes, have been blurred.

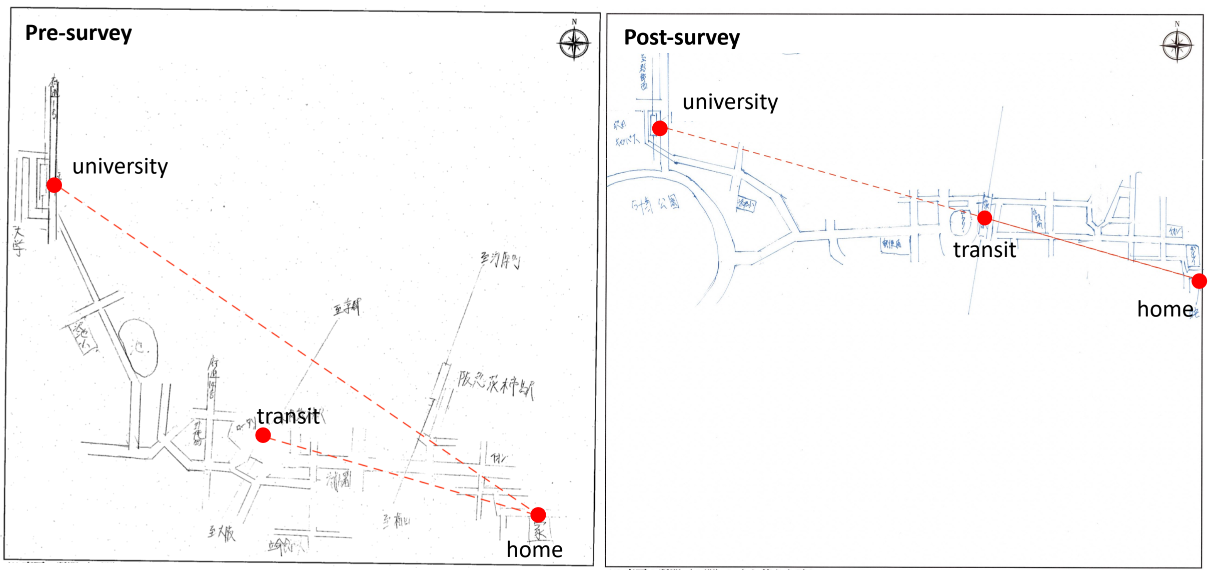

Figure 3.7 An example of sketch map with improvements in both cognitive distance and direction.

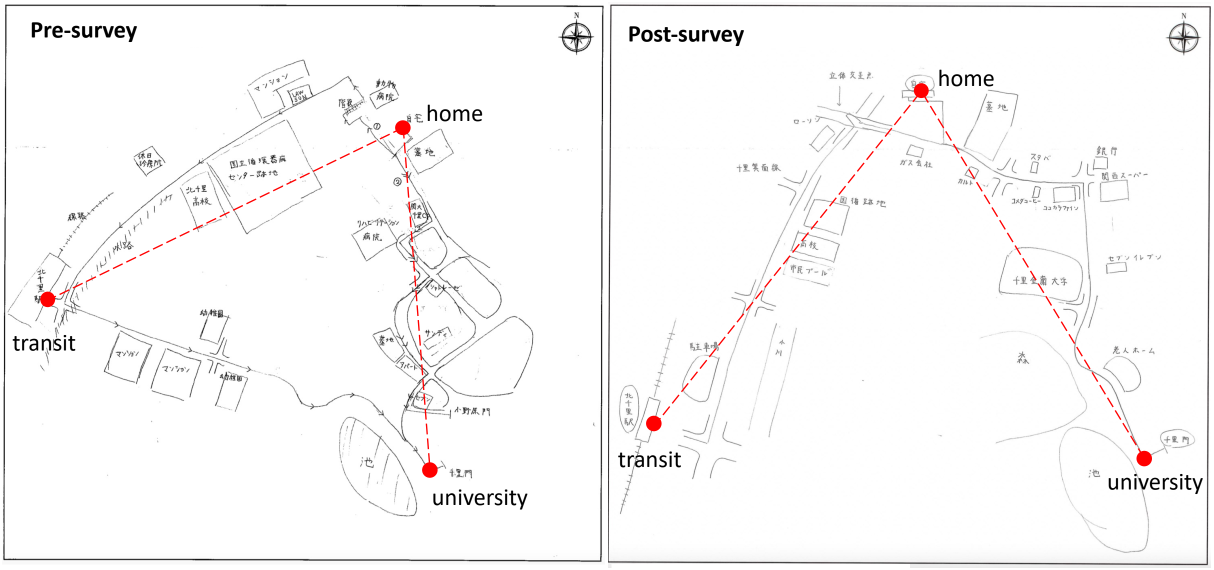

Figure 3.8 An example of sketch map with an improvement in cognitive distance with no change in cognitive direction.

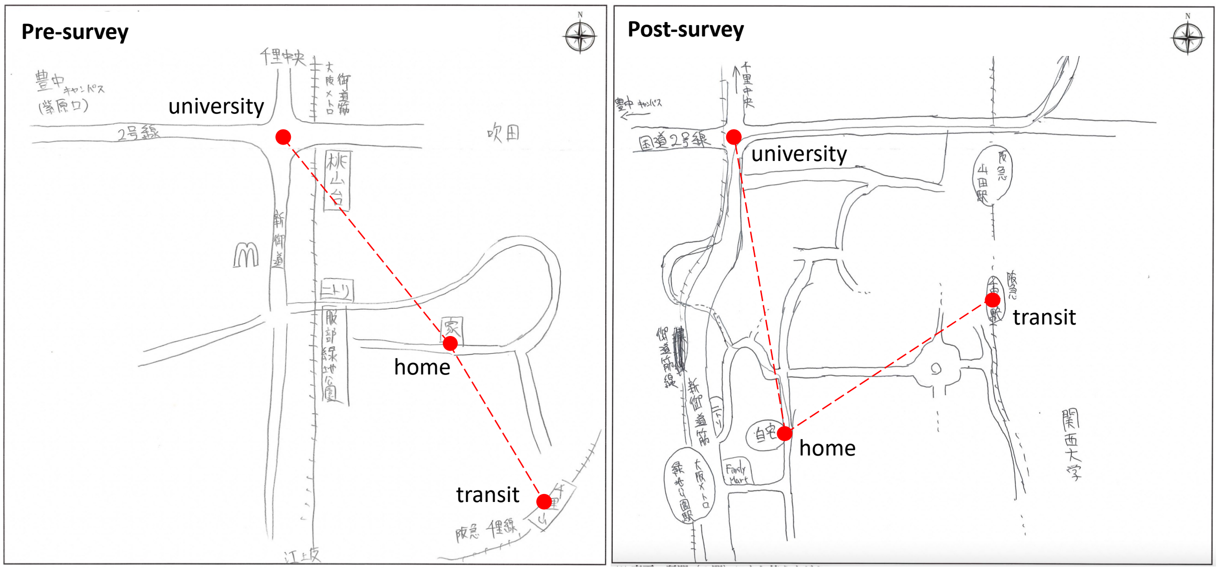

Figure 3.9 An example of sketch map with an improvement in cognitive direction with no improvement in cognitive distance.

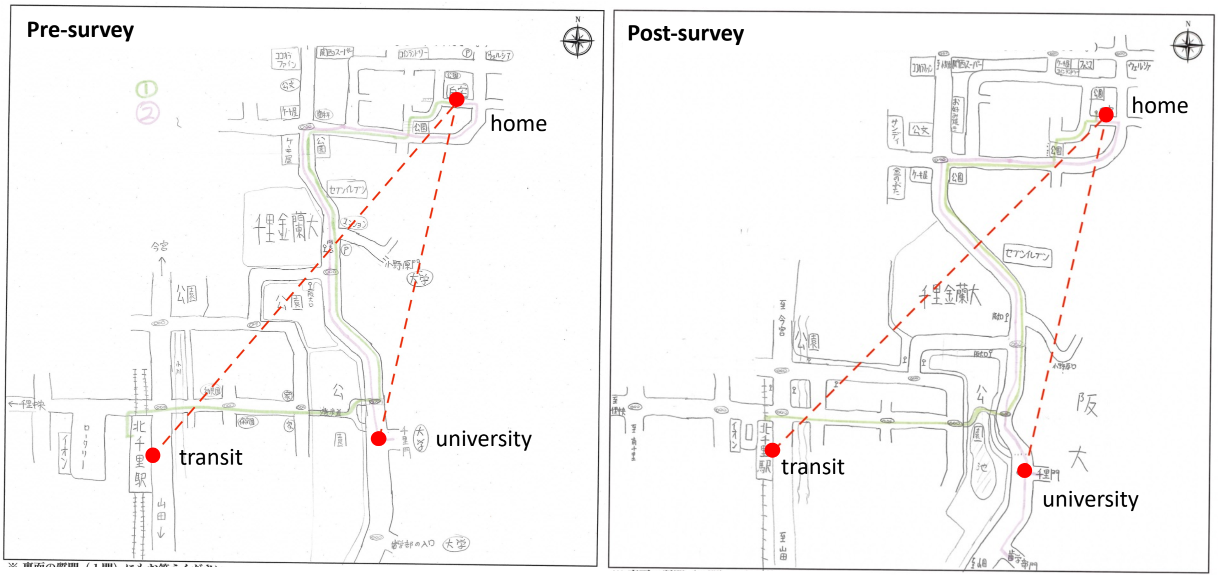

Figure 3.10 An example showing almost no change between the pre- and postmaps.

The examples highlight varying trends in participants' changes in cognitive distance and direction knowledge. **Figure 3.7** demonstrates improvements in both dimensions: cognitive distance accuracy increased from ρ_{dist} = 0.751 to ρ_{dist} = 0.921, and cognitive direction accuracy improved from θ_{dir} = 0.894 to θ_{dir} = 1.000. **Figure 3.8** shows improvement in cognitive distance (*pre*-ρ_{dist} = 0.699, *post*-ρ_{dist} = 0.847), while cognitive direction remained almost unchanged (*pre*-θ_{dir} = 0.750, *post*-θ_{dir} = 0.739). **Figure 3.9** presents a case with no improvement in cognitive distance (*pre*-ρ_{dist} = 0.190, *post*-ρ_{dist} = 0.166) but a significant enhancement in cognitive direction (*pre*-θ_{dir} = 0.371, *post*-θ_{dir} = 0.961). **Figure 3.10** depicts a participant with no improvement in either dimension; however, prior performance in cognitive direction was already excellent (*pre*-ρ_{dist} = 0.717, *post*-ρ_{dist} = 0.643; *pre*-θ_{dir} = 1.000, *post*-θ_{dir} = 0.983).

These examples illustrate four distinct trends based on whether participants showed improvement in cognitive distance, cognitive direction, or both. The following sections will delve into the interaction effects between these two indicators.

Table 3.3 summarizes the Spearman correlation results for variables derived from the sketch maps. It presents descriptive statistics and correlation matrix of spatial knowledge indicators and the linear distances between participants' home, university, and transit station. Significant positive correlations were observed between pre- and post-survey results, reflecting consistent performance among participants. However, no significant relationships were identified between an individual's ability to perceive distance and direction, suggesting these spatial abilities operate independently.

Table 3.3 Descriptive statistics and correlation matrix.

	pre-ρ_{dist}	*post*-ρ_{dist}	*pre*-θ_{dir}	*post*-θ_{dir}	home-uni. (m)	home-trans. (m)
Descriptive statistics (N=41)						
Mean	0.648	0.725	0.894	0.886	2,264.1	925.2
Min	0.130	0.166	0.372	0.589	50	113
Max	1.000	0.998	1.000	1.000	10,100	2,740
S.D.	0.260	0.260	0.114	0.087	2,012.42	708.89
Correlation matrix						
pre-ρ_{dist}	1.000					
post-ρ_{dist}	0.525**	1.000				
pre-θ_{dir}	0.153	-0.007	1.000			
post-θ_{dir}	0.121	0.078	0.324*	1.000		
home-uni.	-0.563**	-0.322*	-0.198	-0.141	1.000	
home-trans.	0.364*	0.418**	-0.188	-0.013	0.049	1.000

Note: ** Correlation is significant at the 0.01 level. * Correlation is significant at the 0.05 level.

Participants who lived farther from the university or transit tended to draw maps with smaller scales. To investigate whether spatial knowledge varied based on the map scales drawn by participants, Spearman correlation analyses were performed. The findings, presented in **Table 3.3**, provide insights into the spatial distribution of participants' homes, transit stations, and the university, based on actual linear distances (measured in meters). The maximum distance from the participants' home to university was about 10 km, while the nearest one was just 50 m. The average distance between home to transit was 925.2 m, with a maximum value of 2,740 m. Significant negative correlations indicated that participants living farther from the university drew maps with smaller scales, reducing their accuracy in perceiving relative distances. Conversely, positive correlations were observed between relative distance accuracy and the distance from home to transit.

Spatial Knowledge and On-Road Experience

Tests were conducted to explore potential group differences based on socio-demographic factors and prior on-road experiences. An independent sample t-test compared participants who drove cars more than once a month ($n = 24$) with those who had no or infrequent driving experience ($n = 17$). While the results were not statistically significant, trends indicated group differences, as shown in **Figure 3.11**. In the presurvey, participants with more on-road experience demonstrated higher accuracy in cognitive distance ($t(39) = 1.149$, $p = 0.257$) and cognitive direction ($t(39) = 1.886$, $p = 0.067$). In the postsurvey, both groups improved in cognitive distance accuracy, with the experienced group performing better. The t-test results for cognitive distance accuracy were $t(39) = 0.667$, $p = 0.508$, and for cognitive direction accuracy were $t(39) = 1.588$, $p = 0.120$.

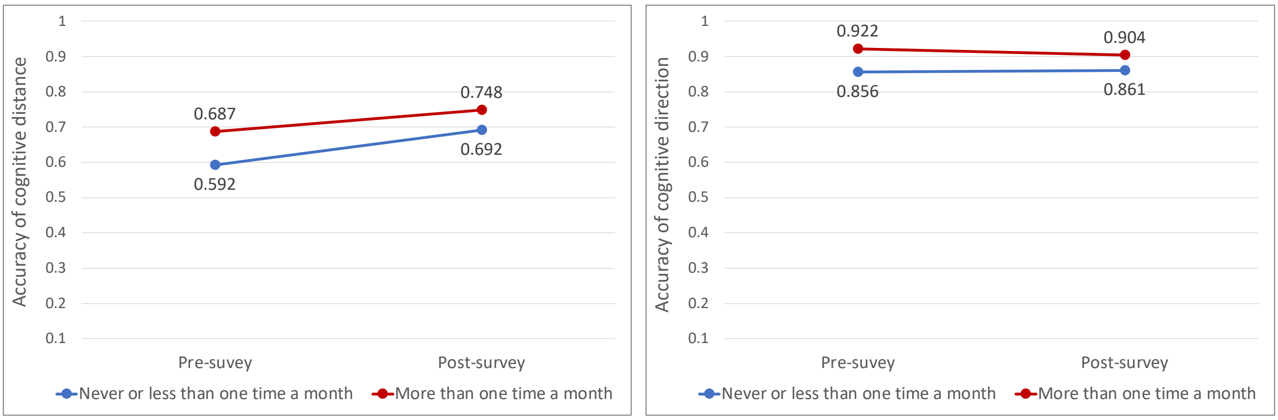

Figure 3.11 The performance of participants' accuracy of cognitive distance and cognitive direction depending on prior on-road experiences.

3.4.2 Relationships between User Attitudes and Spatial Knowledge

Descriptive Statistics

Table 3.4 shows the descriptive statistics, including mean and standard deviation for the items regarding user motivations. **Table 3.5** presents the results for post-survey items regarding users' satisfaction, lifestyle changes, and concerns.

Table 3.4 Pre-survey on motivations to adopt to an electric mobility.

Items (N=41)		Mean	S.D.
Functional/Instrumental motivations (1 = no expect to 4 = strongly expect)			
IM1	Through riding a E2W, I can move freely and smoothly on the roads	3.39	0.628
IM2	I am able to travel over a larger area than before using a E2W	3.07	1.058
IM3	Through riding a E2W, I am able to move faster	2.98	1.151
IM4	Because the batteries are swappable, there is no need to wait for recharge	3.15	0.910
Experiential/Hedonic motivations (1 = disagree to 4 = strongly agree)			
HM1	I join in this project because I am interested in powered two-wheelers	3.41	0.774
HM2	I join in this project because I am interested in electric two-wheelers	3.17	0.803
HM3	I join in this project because I am interested in the battery swapping mechanism	3.00	0.866
HM4	I join in this project because I like riding two-wheelers	3.27	0.923

Table 3.5 Post-survey on satisfactions, changes in lifestyles, and concerns.

Items (N=40)		Mean	S.D.
Functional/Instrumental satisfaction (1 = dissatisfied to 5 = satisfied)			
IS1	Through riding a E2W, I have been able to move freely and smoothly on the roads	4.68	0.694
IS2	I have been able to travel over a larger area than before using a E2W	4.40	0.928
IS3	Through riding a E2W, I have been able to move faster	4.43	1.035
IS4	Because the batteries are swappable, there is no need to wait for recharge	4.58	0.813
Experiential/Hedonic satisfaction (1 = decreased to 5 = increased)			
HS1	Interests in powered two-wheelers	4.50	0.784
HS2	Interests in electric two-wheelers	4.33	0.859
HS3	Interests in battery swapping mechanism	4.35	0.700
HS4	Interests in riding two-wheelers	4.47	0.877
Satisfactions regarding the battery-swappable mobility (1 = dissatisfied to 5 = satisfied)			
BS1	Driving range of a fully charged E2W	2.25	1.104
BS2	Driving range when considering battery swapping services	2.95	1.085
BS3	Time spent on swapping the batteries	4.55	0.815
BS4	Battery-swappable E2W fits to my lifestyle	4.05	1.085
Lifestyle changes (1 = disagree to 4 = strongly agree)			
LS1	Expanded range of daily activities	2.83	1.010
LS2	Increased visits to nearby café and commercial facilities	2.42	1.059
LS3	Increased interests in electric-mobility in addition to E2W	3.00	1.013
Concerns (1 = not concerned to 4 = strongly concerned)			
CN1	Increased likelihood of being involved in a traffic accident	2.50	0.987
CN2	Battery charge runs out while driving	2.93	1.095

Note: E2W refers to electric two-wheelers.

Relationships between Presurvey Items and Spatial Knowledge

Table 3.6 presents the Spearman correlation results for each item in the prequestionnaire. Significant relationships were observed between users' functional/instrumental motivations and their prior spatial knowledge. Specifically, participants with higher cognitive distance accuracy showed greater expectations of traveling across a larger area (IM2: $r = 0.316$, $p < 0.05$). Additionally, a correlation analysis examined whether users' initial attitudes influenced their environmental perception, as reflected in their postmaps. The results revealed a significant relationship between cognitive direction accuracy and experiential/hedonic motivation, indicating that participants with a stronger personal interest in electric two-wheelers before the pilot project were more likely to develop improved cognitive direction after using the mobility service (HM2: $r = 0.373$, $p < 0.05$).

Table 3.6 Spearman correlations between motivations and spatial knowledge.

Items		Pre-survey		Post-survey	
		pre-ρ_{dist}	*pre*-θ_{dir}	*post*-ρ_{dist}	*post*-θ_{dir}
IM1	Move freely and smoothly	0.073	0.052	-0.029	0.262
IM2	Move faster	0.316*	0.091	0.168	0.249
IM3	Interest in powered two-wheelers	0.217	0.106	0.181	0.207
IM4	Interest in battery swapping	-0.033	0.224	0.039	0.071
HM1	Move freely and smoothly	0.173	0.030	0.111	0.262
HM2	Move faster	0.061	0.283	-0.185	0.373*
HM3	Interest in powered two-wheelers	-0.172	0.238	-0.272	0.012
HM4	Interest in battery swapping	0.144	0.029	-0.083	0.281

Note: ** Correlation is significant at the 0.01 level. * Correlation is significant at the 0.05 level.

Relationships between Post-Survey Items and Spatial Knowledge

Table 3.7 illustrates the correlations between user attitudes and respondents' post-survey spatial knowledge as well as changes in spatial knowledge. The variable "changes in spatial knowledge" represents the differences between pre- and post-survey values, quantifying improvements in cognitive distance and direction. Higher positive change values indicate greater enhancements following mobility travel experiences.

Significant relationships were identified between cognitive distance and user satisfaction with the charging service. Participants with better cognitive distance accuracy reported higher satisfaction with battery swapping times (BS3: $r = 0.344$, $p < 0.05$) and expressed less concern about running out of battery charge while driving (CN2: $r = -0.414$, $p < 0.01$).

For cognitive direction, participants with greater direction knowledge exhibited higher experiential/hedonic satisfaction. These participants expressed increased interest in electric two-wheelers (HS2: $r = 0.456$, $p < 0.01$), the battery swapping system (HS3: $r = 0.341$, $p < 0.05$), and other electric mobility options (LS3: $r = 0.423$, $p < 0.05$). Additionally, participants who showed more significant improvements in cognitive direction experienced positive changes in their daily activity patterns, including an expanded range of activities (LS1: $r = 0.452$, $p < 0.01$) and more frequent visits to nearby cafés and commercial facilities (LS2: $r = 0.359$, $p < 0.05$). However, these participants also reported lower satisfaction with the charging time of the battery swapping system (BS3: $r = -0.430$, $p < 0.01$).

These findings underscore the influence of spatial knowledge on user attitudes toward the electric mobility system. Variations in cognitive abilities were linked to differences in satisfaction levels and concerns, particularly regarding driving range and charging issues.

Table 3.7 Spearman correlation between satisfactions and changes in spatial knowledge.

Items		Post-survey		Changes in spatial knowledge	
		$post\text{-}\rho_{dist}$	$post\text{-}\theta_{dir}$	ρ_{dist}_change	θ_{dir}_change
IS1	Move freely and smoothly	-0.210	-0.064	-0.193	-0.095
IS2	Travel larger area	0.162	0.122	0.004	0.134
IS3	Move faster	0.052	0.122	-0.127	0.108
IS4	No need to wait for recharge	-0.079	-0.034	-0.217	-0.258
HS1	Interest in powered two-wheelers	-0.002	0.181	-0.035	0.115
HS2	Interest in electric two-wheelers	-0.033	0.456**	0.079	0.271
HS3	Interest in battery swapping	-0.031	0.341*	0.057	0.188
HS4	Like riding two-wheelers	-0.063	0.167	-0.212	0.260
BS1	Driving range of a full-charged EV	-0.105	0.099	-0.258	-0.044
BS2	Driving range with battery-swapping	-0.045	0.302	-0.196	0.171
BS3	Time spent on battery swapping	0.344*	-0.259	0.109	-0.430**
BS4	E2W fits lifestyle	0.230	0.266	0.054	0.036
LS1	Expanded daily activity range	0.000	0.218	0.000	0.452**
LS2	Increased leisure trips	0.011	0.251	0.026	0.359*
LS3	Increased interests in other mobility	-0.084	0.423**	0.094	0.225
CN1	Concerns about traffic accidents	0.008	0.258	0.106	0.205
CN2	Concerns about battery depletion	-0.414**	0.009	-0.173	0.083

Note: ** Correlation is significant at the 0.01 level. * Correlation is significant at the 0.05 level.

Two-Way ANOVA Results

A two-way ANOVA was performed to assess the interaction effect between cognitive distance and cognitive direction on user attitudes. The dependent variables were satisfaction with the driving range of fully charged electric two-wheelers (BS1) and satisfaction with the driving range considering battery-swapping services (BS2). Participants were grouped based on their improvements in cognitive distance and cognitive direction as measured in the postsurvey.

Figure 3.12 illustrates the mean satisfaction scores for each group combination. A significant interaction effect was observed for satisfaction with the driving range of fully charged vehicles, $F(1, 36) = 4.973$ and $p < 0.05$. The findings indicate that participants who improved in cognitive distance showed lower satisfaction with the driving range if they also improved in cognitive direction. This aligns with the correlation results, where participants with better cognitive distance had higher expectations for traveling greater distances and expressed less concern about battery depletion while driving. Conversely, participants with improved cognitive direction reported greater interest in mobility options and positive lifestyle changes, such as an expanded travel area and increased activity frequency. This suggests that the impact of cognitive distance may vary based on a user's aspirations for mobility trips, which are closely tied to cognitive direction.

For satisfaction with the driving range when considering battery-swapping services, no significant interaction effect was found, ($F(1, 36) = 1.339$, $p = 0.255$). However, a simple main-effects analysis revealed that cognitive direction significantly influenced satisfaction with the driving range, ($p < 0.05$). The results highlight the role of the battery-sharing mechanism in enhancing user satisfaction, particularly for participants who improved in both cognitive distance and direction. Satisfaction scores rose notably from 1.64 to 2.64 when battery-swapping services were considered, indicating their effectiveness in addressing users' desire to travel over larger areas.

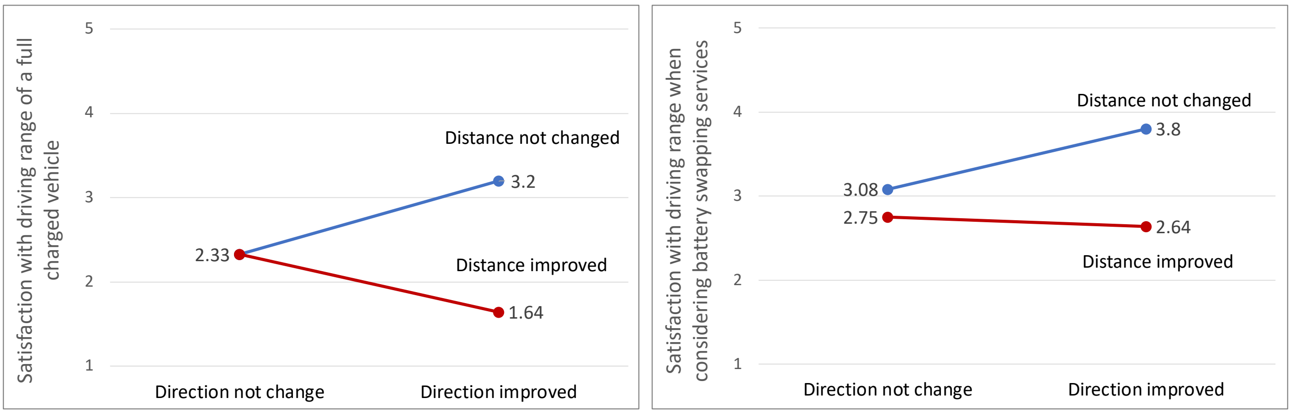

Figure 3.12 Interaction effects of cognitive distance and direction on satisfaction with the driving range of BSET.

3.4.3 Relationships between Spatial Knowledge and Travel Behaviors

This study analyzed participants' travel patterns using vehicle tracking data. **Table 3.8** presents the results of the correlation tests, highlighting significant negative relationships between cognitive direction accuracy and residual battery power. Participants with better post-cognitive direction ($r = -0.356,\ p < 0.05$) or greater improvements in direction knowledge ($r = -0.340,\ p < 0.05$) tended to swap batteries at lower residual power levels. This suggests that enhanced spatial knowledge may enable participants to better manage battery usage during their trips.

Table 3.8 Spearman correlations between spatial knowledge measures and vehicle tracking data.

Indicators	Post-survey		Changes in spatial knowledge	
	post-ρ_{dist}	*post*-θ_{dir}	ρ_{dist}_*change*	θ_{dir}_*change*
Trip chains	-0.032	0.301	-0.025	0.157
Total distances	-0.187	0.202	-0.009	0.088
Battery swapping times	-0.091	0.114	0.121	-0.017
Residual power	-0.063	-0.356*	-0.274	-0.340*

Note: ** Correlation is significant at the 0.01 level. * Correlation is significant at the 0.05 level.

Trip-Chaining Behaviors

Over the 3-month study period, 2,422 trip chains from 40 participants were analyzed. Principal Component Analysis (PCA) identified three principal components, explaining 72.8% of the variance and meeting established criteria, including eigenvalues >1.0, factor loadings >5%, and a cumulative proportion >60% (Maskey, Fei, & Nguyen, 2018) (**Table 3.9**). Using the PCA scores, a cluster analysis identified four distinct clusters (A to D) comprising 955, 369, 549, and 549 trip chains, respectively. **Table 3.10** summarizes the cluster means for the principal components and travel pattern indicators, offering insights into each cluster's characteristics.

Clusters A and C featured smaller travel ranges, with shorter distances and smaller convex hulls. Cluster A represented quick, short trips with fewer destinations and brief stays. In contrast, cluster C involved more frequent stops, averaging 2.7 stops and 82 minutes at sub-destinations, demonstrating flexible electric two-wheeler usage for varied purposes within short trips.

Clusters B and D, by comparison, involved longer travel distances. Cluster B reflected commuting patterns, with fewer destinations and shorter sub-destination stays. Meanwhile, Cluster D encompassed extended journeys with multiple stops and longer stays at both main and sub-destinations, illustrating the potential of battery-swappable electric vehicles to support diverse, long-distance travel needs.

The distribution of trip chains across clusters highlighted the capability of small-format vehicles to meet users' daily travel needs while offering enhanced mobility freedom. Notably, 62.1% of trip chains (clusters A and C) involved shorter journeys, whereas 45.3% (clusters C and D) comprised trips with multiple purposes. This analysis of trip-chaining behaviors unveiled distinct travel patterns, emphasizing the potential of electric mobility systems to address diverse travel needs effectively.

Table 3.9 PCA results using 11 indicators about trip-chaining behaviors.

	PC 1	PC 2	PC 3
Eigenvalues	4.8872	1.7609	1.3544
Proportion of variance	0.4443	0.1601	0.1231
Cumulative proportion	0.4443	0.6044	0.7275
Variables			
Number of destinations	-0.756	0.237	0.157
Distance to the main destination	-0.434	-0.809	0.093
Width on the basis of main destination	-0.825	0.205	-0.179
Ratio of width to distance of main destination	-0.164	0.250	0.360
Distance to the farthest destination	-0.737	-0.613	0.140
Width on the basis of farthest destination	-0.876	0.205	-0.337
Ratio of width to distance of farthest destination	-0.574	0.507	-0.373
Convex hull (m^2)	-0.862	-0.013	-0.245
Total travel distance	-0.875	-0.303	0.143
Staying duration at the main destination	-0.220	0.248	0.696
Staying duration at the sub-destination	-0.472	0.345	0.568

Table 3.10 The mean values of principle component scores of each cluster and travel pattern indicators.

Cluster	A	B	C	D
Number of chains	955	369	549	549
Proportion (%)	39.4	15.2	22.7	22.7
PC 1	1.560	0.080	0.200	-2.968
PC 2	0.159	-1.358	0.967	-0.332
PC 3	-0.062	0.354	-0.421	0.292
Mean value				
Number of destinations	1.3	2.0	2.7	4.4
Dis. to the main destination (km)	1.71	5.59	1.74	5.40
Dis. to the farthest destination (km)	1.65	5.59	2.13	7.22
Total travel distance (km)	5.60	16.73	9.06	26.91
Staying duration at main destination (h)	4.5	5.8	6.8	14.3
Staying duration at sub-destination (min)	6	41	82	298

The descriptive statistics in **Figure 3.13** examine whether changes in participants' spatial knowledge correlated with their trip-chaining behaviors. Participants were grouped based on improvements in cognitive distance and cognitive direction. Independent sample t-tests found no significant differences in trip-chaining behaviors between the groups for either variable.

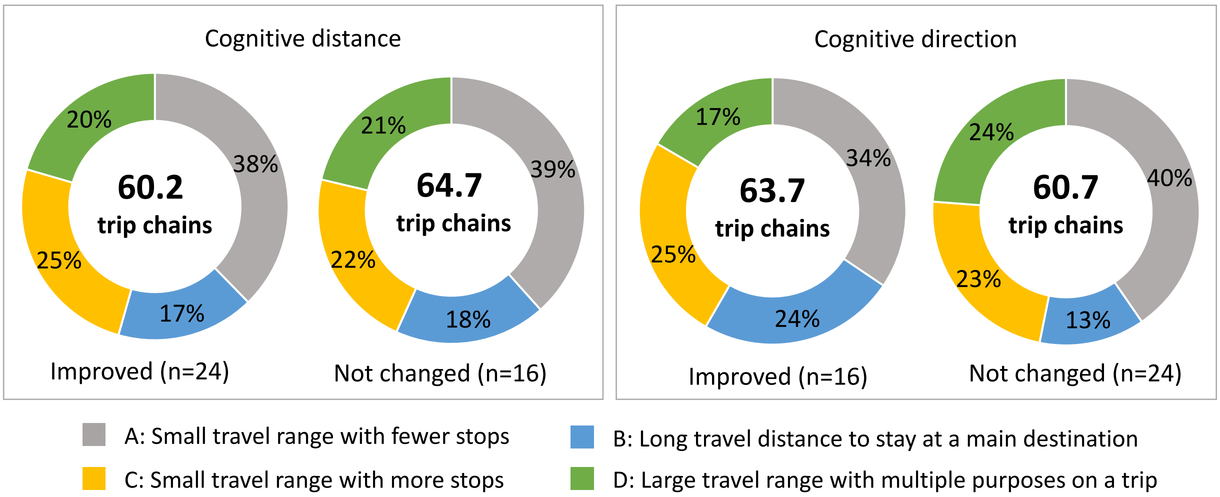

Figure 3.13 The proportion of trip chains in each category based on users' changes in spatial knowledge.

3.4.4 Results of Structural Relationship Analysis

The SEM analysis investigated the distinct roles of cognitive direction and cognitive distance, examining their direct and indirect effects on mobility adoption, particularly concerning travel range and EV charging issues. **Figure 3.14** presents the estimated model with standardized path coefficients and significance levels. The model demonstrated an acceptable fit with the sample data (X^2/df=1.37, CFI = 0.94, TLI = 0.91, GFI = 0.86, and RMSEA = 0.06) (Hair, 2009).

Both cognitive direction and cognitive distance positively influenced user satisfaction with functional/instrumental purposes. Specifically, the post-survey levels of cognitive direction ($\beta = 0.40$, $p < 0.01$) and cognitive distance ($\beta = 0.38$, $p < 0.01$) significantly impacted satisfaction with the time spent on battery swapping. Satisfaction with charging time, in turn, had a strong positive effect on users' ability to travel over larger areas ($\beta = 0.56$, $p < 0.001$) and contributed to overall satisfaction, including alignment with lifestyle needs ($\beta = 0.66$, $p < 0.001$) and an expanded range of daily activities ($\beta = 0.41$, $p < 0.001$).

Cognitive direction also strongly influenced hedonic experiences. Improved cognitive direction significantly enhanced interest in riding two-wheelers ($\beta = 0.68$, $p < 0.001$) and subsequently increased interest in other electric mobility services ($\beta = 0.40$, $p < 0.01$). These findings corroborate the interaction effects discussed in the two-way ANOVA section, highlighting how cognitive distance and direction jointly satisfy users' desires for more frequent trips and broader travel areas.

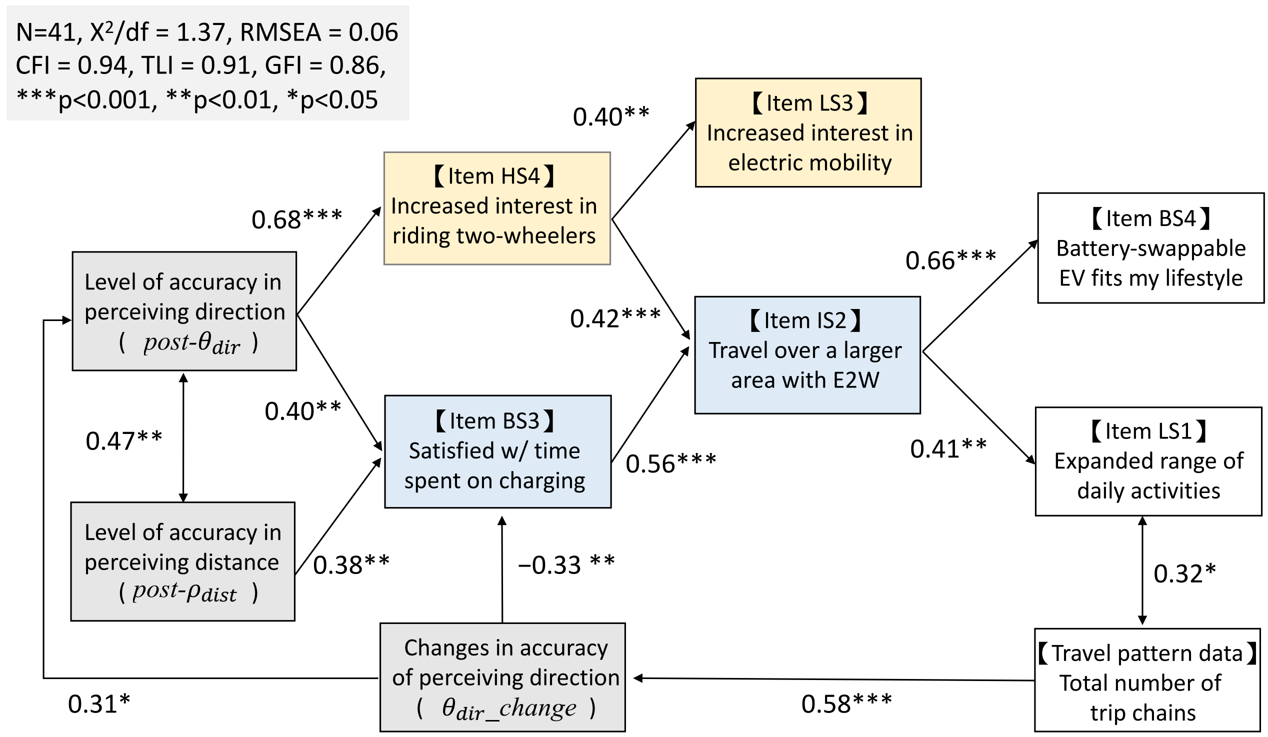

Figure 3.14 SEM analysis results. Factors colored in yellow are regarding experiential/hedonic values, and factors in blue are related to functional/instrumental 753 satisfaction.

Additionally, a significant positive correlation was observed between lifestyle changes, such as an expanded range of daily activities, and the total number of trip chains recorded in the vehicle tracking data. Notably, the total number of trip chains positively influenced improvements in cognitive direction ($\beta = 0.58$, $p < 0.001$) and higher spatial knowledge levels in the postsurvey ($\beta = 0.31$, $p < 0.05$). However, users who demonstrated significant improvements in cognitive direction showed a negative effect on satisfaction with the time spent on charging ($\beta = -0.33$, $p < 0.01$). This finding aligns with the two-way ANOVA results, emphasizing the need to address user concerns about the battery-swapping system as spatial cognition improves with accumulated experiences.

3.5 Discussions

This study utilized quantified sketch maps as a flexible and effective method for assessing spatial knowledge in large-scale environments. The proposed indicators facilitated robust quantitative analyses, including hypothesis testing, group comparisons, and evaluations of travel patterns. By bridging spatial cognition with spatial behavior, the study provided empirical insights into how spatial experiences influence user intentions and the adoption of a battery-sharing mobility system. The findings aim to inform service providers and urban designers, offering practical recommendations. The key outcomes of the study are summarized below, addressing each research question.

Firstly, the results confirm that accumulating spatial experience enhances spatial knowledge, addressing the first research question. Participants with more prior driving experience demonstrated better spatial abilities in accurately recognizing distances and directions. After three months of using the BSET, participants showed a significant improvement in the accuracy of cognitive distance. Additionally, vehicle tracking data corroborated these findings, revealing that participants who completed more trips exhibited notable improvements and higher accuracy in perceiving direction.

Secondly, the study highlights the distinct effects of cognitive distance and cognitive direction on user motivation and satisfaction, addressing the second research question. Participants with better cognitive distance had higher expectations for traveling across larger areas and expressed fewer concerns about charging issues, leading to greater overall satisfaction. Previous research supports that psychological distance influences perceived control, with closer psychological proximity associated with a stronger sense of control (Huang & Zhang, 2023). Similarly, participants with a better grasp of cognitive distance likely had a more accurate understanding of the proximity and availability of charging stations, which reduced their concerns about battery depletion and enhanced their satisfaction.

Another notable finding suggests that improved cognitive direction significantly enhances the enjoyment of mobility travel. Users with better cognitive direction demonstrated stronger spatial orientation and navigational abilities, making them more inclined to explore diverse mobility options and destinations. Prior research has established a link between increased regional mobility—characterized by frequent trips and broader travel areas—and improved navigational performance (Davis, Gurven, & Cashdan, 2023). However, the influence of personality traits, emotions, and cognitive differences on spatial exploration tendencies remains underexplored (Davis, Stack, & Cashdan, 2021).

This study provides empirical evidence that enhanced navigational skills in urban environments increase users' interest in mobility and spatial exploration. From an environmental affordance perspective, a better understanding of the surrounding environment allows travelers to identify opportunities that meet their needs. The findings reveal that users with improved spatial knowledge reported greater satisfaction with the battery-sharing system, positive changes in daily activity patterns, and increased interest in mobility travel. Additionally, users with enhanced directional knowledge displayed more efficient battery-swapping behaviors.

The two-way ANOVA analysis identified an interaction effect between cognitive distance and direction knowledge. The results indicate that participants with improved cognitive distance exhibited lower satisfaction with the driving range of the vehicle when their cognitive direction also improved. This trend reflects a "treadmill effect," where heightened aspirations reduce satisfaction levels (Kahneman, Kahneman, & Tversky, 2003), underscoring the need for more adaptable solutions to meet diverse travel demands. Additionally, the analysis validated the effectiveness of the battery-sharing mechanism in alleviating concerns related to prolonged charging times and limited EV range.

To address the third research question, this study examined users' travel patterns through home-based trip chains. Correlation analysis revealed that users with better directional knowledge demonstrated greater control over battery residual power. However, no significant differences in trip-chaining behaviors were observed based on participants' improvements in spatial knowledge. While the analysis provided valuable insights into daily activity-travel patterns, it did not account for users' battery-swapping behaviors. Future research could explore diverse activity-travel patterns more comprehensively by incorporating a recharge cycle perspective.

This study provides practical insights, emphasizing the importance of supporting SEV users in developing a comprehensive understanding of urban environments to improve navigation, optimize activities, and enhance travel enjoyment. Addressing concerns about battery life, service providers and vehicle designers can enhance user experiences by integrating real-time data on residual battery power and estimated travel ranges into vehicle dashboards and mobile applications. While GPS technologies have simplified urban navigation, the formation of cognitive maps plays a crucial role in accessing potential opportunities and informing travel decisions (Mondschein et al., 2006). Individuals' decisions to travel or stay are influenced by their perceived distances to various destinations (Cadwallader, 1976).

For urban planners and public administrators, our findings stress the importance of improving spatial legibility within urban settings. Enhancing access to essential resources, such as recharging stations and key venues like commercial and leisure facilities, is vital for facilitating efficient urban navigation. Spatial legibility, the ease with which individuals can comprehend and navigate through an environment, is instrumental in urban design. This concept not only bolsters accessibility and enriches the urban experience but also significantly impacts the acquisition of spatial knowledge (Koseoglu & Onder, 2011). Environments that are coherent, understandable, simple, and well-organized promote quicker and more effective learning of spatial layouts, thereby supporting better spatial experiences.

This study is limited by the lack of a control group and a small sample size, restricting definitive conclusions about the impact of mobility travel on spatial knowledge. Despite this, respondents' mode choices, such as limited prior access to motorized vehicles, provide partial insights. Future research should include a control group, larger samples, and explore intervention mechanisms and generalizability. This study highlights the roles and interaction effects of cognitive distance and direction in BEV usage and urban navigation, suggesting further exploration of how information provision influences user experiences and BEV travel performance.

3.6 Conclusions

In recent years, the advancement of virtual power plants represents a significant Cyber aspect that interacts with urban environment (Urbs) by enabling more efficient energy distribution within urban grids. The vehicle-grid integration (VGI) systems allow EVs not only to draw power from the grid but also to feed energy back into it during peak times, effectively turning vehicles into mobile energy storage units. This technology enhances the energy sustainability of urban areas and aligns with urban planning goals to reduce energy consumption and greenhouse gas emissions (Inci, Savrun, & Çelik, 2022). Beyond technical innovations, vehicle-to-vehicle (V2V) wireless charging introduces a flexible and rapid energy exchange method, reducing reliance on dense charging station networks (Mou, Zhao, & Gladwin, 2018). In typical V2V systems, energy is transferred from one battery electric vehicle (BEV) to charge another (İnci, Büyük, & Özbek, 2022). The ongoing development of battery-sharing EVs addresses infrastructure challenges and accelerates electric mobility adoption.

Overall, the interaction between Cyber and Urbs in this context is multifaceted, encompassing energy management, infrastructure design, behavior adaptation, and community development. This interaction aims not only to optimize technological functionalities within urban settings but also to enhance the quality of life by improving emotional experiences and meeting the daily activity needs of residents. Aligned with the principles of compassionate mobility, this approach prioritizes accessible and convenient mobility options that cater to a diverse range of needs and preferences. This holistic strategy goes beyond merely enhancing physical infrastructure; it nurtures a supportive community atmosphere, fostering a deeper connection between residents and their urban environment.

This study involved university students in a pilot mobility service, where they acted as both service users and active community members within a community-based BEV framework. The findings reveal a coevolutionary relationship between the transition to battery-sharing EVs and users' enriched spatial experiences and cognitive knowledge. On an individual level, enhanced spatial knowledge and experiences increase enjoyment of urban travel, fostering greater interest and intent to use mobility services. These factors support social acceptance and adoption of BEVs as a sustainable mobility option. At the community level, this research emphasizes the creation of a virtuous cycle. Enriched spatial experiences and knowledge motivate users to contribute to improving local streets, roads, and urban spaces. Such collaborative efforts benefit road users and promote sustainable neighborhood development, enhancing the quality of life within local communities.

4 Applying Psychometrics and Cultural Theory to Understand Risk Perception and Behavior Formation for Sustainable Safety Culture

Summary: This chapter delves into leveraging the Urbs—context and traffic environment—and Civitas—safety cultural and local habits—to promote safe mobility and enhance livability. This exploration begins with a critical review of the authors' previous work on the effectiveness of cross-sector safety educational programs in Vietnam, aimed at improving road safety awareness among drivers. This review identifies gaps in understanding the behavioral determinants of traffic accidents and sets the stage for a refined methodology.

Building upon these insights, the chapter employs psychometric and cultural theory frameworks to examine the mechanisms underlying behavioral formation. This approach is applied through a large-scale questionnaire survey of 1,200 motorcyclists in Thailand, exploring how cultural and contextual factors shape risk perceptions and influence behavioral responses. Structural Equation Modeling (SEM) is used to test the hypothesized relationships between these variables.

The findings reveal that emotional and efficacy perceptions, along with contextual factors and habituated actions, significantly impact risk perception and influence behaviors such as the adoption of protective measures or engagement in violations. Notably, habituated actions emerge as having a profound direct impact on accident occurrence. By examining how individuals perceive and respond to risks within their specific cultural contexts, this study provides a comprehensive understanding of behavior drivers and their implications for road safety.

Incorporating psychometric and cultural theories provides a robust framework for identifying patterns in behavior and risk perception. This perspective not only enriches our understanding of driver behavior formation but also supports the development of culturally adaptable and effective safety interventions, thus enhancing the overall livability and safety of urban environments.

This chapter is a version of the following publication: Chou, C. C., Yoh, K., Inoi, H., Yamaguchi, T., & Doi, K. (2022). Effectiveness evaluation on cross-sector collaborative education programs for traffic safety toward sustainable motorcycle culture in Vietnam. IATSS research, 46(2), 258-268.

4.1 Introduction

While emerging small-format electric mobility solutions are gaining traction in developed urban contexts, developing countries—particularly those heavily reliant on motorcycles or three-wheelers—face unique challenges in achieving sustainable mobility. In these regions, small-format mobility is not a recent innovation; motorcycles have long played a dominant role in daily transportation. Ensuring the safety of motorcyclists, therefore, becomes a critical component of sustainable transport strategies. Global statistics indicate that 90% of road fatalities occur in low- and middle-income countries, despite these nations accounting for only 60% of the world's vehicles (World Health Organization, 2021). These regions have extensive experience addressing traffic accidents, offering valuable lessons for improving the safe adoption of small-format mobility solutions worldwide.

Risk perception is a critical factor in shaping behavior and, consequently, in influencing accident rates. However, perceptions of risk can vary significantly across regions. Driver training programs have long been regarded as essential for addressing this issue, focusing on fostering safer attitudes, improving driving skills, enhancing risk perception, and reducing risk-taking behaviors. Despite these efforts, many motorcyclists in certain regions prefer informal learning, relying on personal experience to acquire skills and knowledge over time (Blackman & Haworth, 2010). This practice is particularly prevalent in motorcycle-dependent areas, especially in developing countries, where riders often begin at a young age with little to no formal guidance (Woratanarat er al., 2013). Consequently, risky behaviors are widespread and represent a major cause of riding-related injuries (Wong et al., 2010).

Research highlights the variability in the effectiveness of motorcycle training programs across regions, largely influenced by societal and cultural differences (Haworth & Mulvihull, 2005; Araujo et al., 2017). For instance, a study in Australia revealed that even experienced riders often dismissed formal training as "common sense," yet continued to engage in unsafe riding practices (Rowden et al., 2009). These findings emphasize the critical role of cultural and psychological factors in shaping risk tolerance, suggesting that training programs alone may be insufficient. Addressing these deeper influences is essential for promoting safer riding behaviors and offers valuable insights for designing more effective training programs.

Risk perception, defined as individuals' subjective judgments about the likelihood of negative events such as injury or death, plays a crucial role in how people prioritize hazards and respond to them (Slovic, 2016). Sandman (1989) conceptualized risk as a combination of two elements: hazard, which refers to the technical aspects of risk, and outrage, encompassing non-rational responses such as fear or anxiety. Slovic (1987) further demonstrated that people perceive risk not solely based on the likelihood of harm but also through emotional and psychological dimensions, indicating that risk perception involves both rational evaluations and emotional responses. Importantly, he highlighted that risk perception is subjective and varies significantly across individuals and cultures, shaped by factors such as personal experiences, cultural background, and values.

Cultural contexts strongly influence how individuals perceive road-related risks, shaping what drivers consider acceptable or necessary behaviors. These perceptions often vary regionally. The concept of traffic safety culture captures shared patterns of behavior, norms, and societal expectations that influence how communities assess and respond to road safety risks (Nævestad et al., 2020). These shared expectations can create social pressures to conform to what is deemed "normal" within a community. While values prioritizing safety can promote safer driving behaviors, they can also inadvertently encourage risky practices through false consensus—the assumption that others share the same attitudes toward risk.

Although research demonstrates that risk perception significantly affects behavior and is a key element in health-related interventions (Ferrer & Klein, 2015), traffic safety interventions are often evaluated primarily by outcomes such as reductions in injuries and fatalities (Araujo et al., 2017). While these outcomes are important, many evaluations fail to consider how risk perception shapes behavior or the factors influencing these perceptions. Understanding these dynamics is essential for identifying the strengths and gaps in training programs. To address these gaps, evaluations should be complemented by deeper insights into the factors and mechanisms that shape risk perception and behavior formation. Using frameworks like psychometrics and cultural theory can provide a more comprehensive understanding of how individuals perceive and respond to risks within their cultural context. This approach can lead to more effective, culturally sensitive safety interventions, enhancing the impact of training programs.

This study begins with an overview of the author's related research, summarizing key findings from previous publications and identifying their limitations and unresolved issues. It then discusses the theoretical advancements made in the current PhD research, which incorporates psychometric paradigms and cultural theories into the study of risk perception. A hypothesized causal model is proposed to explain how these frameworks influence driver behavior. This model is tested in Thailand, a region characterized by high road fatality rates and an underdeveloped training system for addressing such issues. The primary objective is to uncover the psychological and cultural factors that underlie risky behaviors among mobility users.

4.2 Overview of Related Work

This section provides an overview of the author's previous publication, titled "Effectiveness Evaluation of Cross-Sector Collaborative Education Programs for Traffic Safety Toward a Sustainable Motorcycle Culture in Vietnam," which is closely related to the current study.

Vietnam has implemented extensive safe-riding programs aimed at fostering a safety culture through diverse activities. This study examines the effectiveness of these initiatives by analyzing motorcyclists' attitudes, behaviors, and accident prevention measures, with a particular focus on psychological changes among participants and non-participants in safety programs. Additionally, the social impacts of cross-sector collaborative education programs and their effects on participants' well-being are evaluated.

4.2.1 Study Contexts

Vietnam has experienced rapid growth in vehicle ownership, with registered vehicles reaching 76.7 million, 93.9% of which are motorized two-wheelers (National Traffic Safety Committee, 2021). The country has the highest density of motorized two- and three-wheelers in ASEAN, with 422 per 1,000 people (Kitamura, Hayashi, & Yagi, 2018). Motorcycles dominate urban traffic, accounting for 74% of the modal share (Huu & Ngoc, 2021), exposing riders to significant accident risks. In 2016, the road traffic fatality rate in Vietnam was 26.4 per 100,000 population, exceeding the Southeast Asian average of 20.7 (World Health Organization, 2018). Despite this, traffic fatalities have declined over the past two decades, from an annual average of 12,010 (2001–2010) to 8,741 (2011–2020), with a progressive reduction observed from 2012 onward (National Traffic Safety Committee, 2021).

To enhance road safety as a cornerstone of sustainability, the Vietnamese government established the National Traffic Safety Committee (NTSC) to coordinate, legislate, and monitor safety strategies. Collaborating with motorcycle manufacturers, including Honda Vietnam Co., Ltd. (HVN), the government has promoted various traffic safety initiatives. HVN, dominating over 80% of the Southeast Asian motorcycle market (Vietnam News Agency, 2021), has been pivotal in road safety education in Vietnam. Key HVN initiatives include:

(1) **Traffic Safety Education Center (TSEC)**: Established in 1999, it provides training for the public, government officials, traffic police officers, and motorcycle dealer instructors. Between 2013 and 2019, over 2,600 traffic police were trained, and safety instructions were offered to all Honda motorcycle customers.

(2) **"I Love Vietnam" Campaign**: Launched in 2003, this TV and social media campaign promotes traffic safety knowledge. By 2019, HVN had educated 10.2 million students through school programs, including teaching materials and instructor training for teachers.

(3) **Helmet Donation Project**: In partnership with the NTSC and the Ministry of Education and Training (MoET), this project donated 4 million helmets to first-grade students nationwide from 2018 to 2019, increasing helmet-wearing rates among 6- to 15-year-olds from 35% in 2017 to 70% in 2019 (Global Alliance of NGOs for Road Safety, 2020).

These collaborative efforts demonstrate a comprehensive approach to improving traffic safety and fostering a sustainable safety culture in Vietnam.

4.2.2 Data

To evaluate the effectiveness and assess the social impact of safety activities, a self-administered questionnaire survey was conducted in Vietnam during the period from 29 July to 3 August in 2020.

Since the HVN education program included a variety of elements and have been implemented across the country. A sample size of 600 valid responses were collected for this study. For further comparison and evaluation, the survey ensured a sample size of 100 non-motorcyclists, and another 100 respondents were motorcyclists that have not participated in HVN activities.

The questionnaire was composed of three sections. The first section investigated demographic data (i.e., gender, age, motorcycle-riding experience), accident experience, and respondents' experience of education and training on motorcycles. The second section consisting of two sets of items, was designed to assess rider's knowledge, attitudes towards road safety, and riding behaviors.

Among the respondents, 34.0% were male and 66.0% female, with the majority aged 20–29 years (48.3%), followed by those aged 30–39 years (40.5%). Most respondents (83.3%) were motorcyclists, primarily riding small motorcycles (66.0%), while 17.3% used medium to large motorcycles. An additional 6.3% (n=100) were moped users, and 100 respondents did not ride motorcycles. Riders with over 5 years of riding experience accounted for 69.3% of the sample. Regarding traffic accidents, 26.6% of motorcycle and moped users reported having experienced at least one accident, while 6.7% had accidents resulting in injury or death within the past year.

Participation in HVN safety activities varied significantly. The "I Love Vietnam" TV program, promoted via social media, saw the highest participation rate (52%), followed by school safety textbooks (47%) and the helmet-donation campaign (31%). Additionally, HVN conducted safe riding skill training programs, including courses for youth at universities or colleges (32%), dealer-organized courses for customers and residents (22%), and classes offered at the Traffic Safety Education Center (TSEC) (64%). Other dealer-hosted courses accounted for 14% participation. For the analysis, respondents who participated in any of these four training programs, focused on both skill-building and classroom instruction, were categorized as participants in the "HVN Safe Riding Program."

4.2.3 Analysis

The respondents were categorized based on their riding experience, participation in rider training, accident experience, and altruistic motivations for safe riding. The effectiveness of training in accident prevention was assessed by comparing accident rates across groups, with an analysis conducted to evaluate differences based on riding experience.

Structural Equation Modeling (SEM) with maximum likelihood estimation was used to explore interrelated relationships among latent variables and constructs, focusing on riders' attitudes and behaviors. A two-stage approach was applied: the first stage involved confirmatory factor analysis (CFA) to validate the measurement model, while the second tested the hypothesized structural model using SEM. Respondents' rider training participation and accident experience were incorporated into the structural model to confirm causal links between education, accidents, attitudes, and behaviors.

For social impact assessment, the study examined the effects of HVN safety activities, measuring individual changes attributable to the organization's interventions. The analysis focused on participants' shifts in thinking post-activity, testing causal relationships between riding confidence, safety awareness, riding joy and comfort, independence, and perspective-taking abilities.

4.2.4 Results and Findings

Descriptive Statistics

Descriptive statistics of the survey items are reported in **Figure 4.1** and **Figure 4.2**.

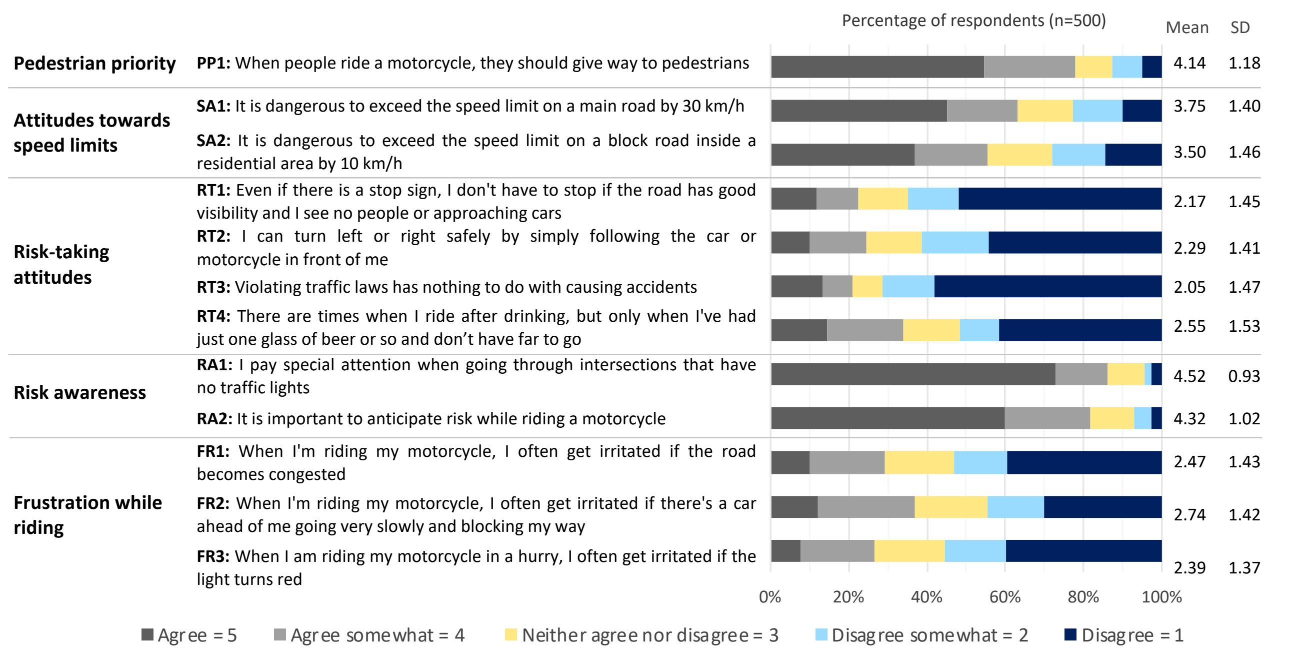

Figure 4.1 Survey items regarding riding attitudes.

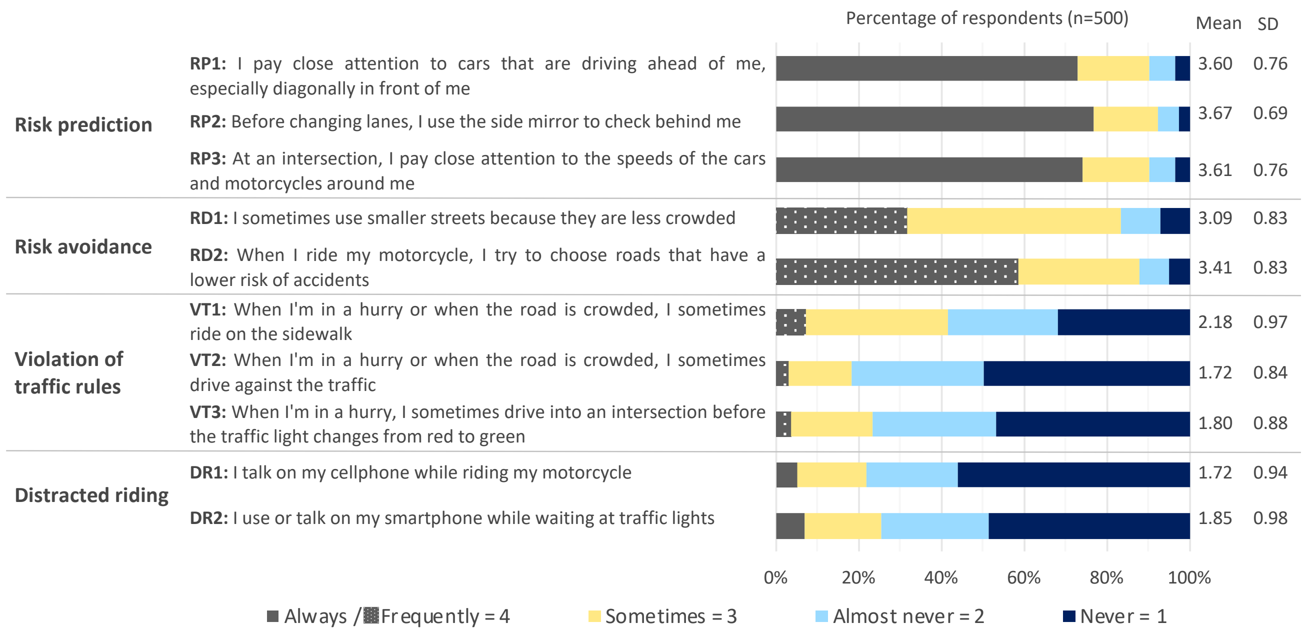

Figure 4.2 Survey items regarding riding behaviors.

Group Comparisons

Table 4.1 presents the effects of demographic characteristics and personal traits on measurement items, with a p-value of less than 0.05 indicating significant differences between groups. Key factors identified as significant include riding experience, participation in the HVN safe riding program, accident experience, and altruistic motivation.

Table 4.1 T-tests results.

Construct	Item	Riding experience		Participate in HVN safe riding program		Accident experience		Altruistic motivation to ride safely	
		< 3 yrs (n=75)	≥ 3 yrs (n=425)	Yes (n=401)	No (n=99)	Yes (n=131)	No (n=369)	Yes (n=371)	No (n=129)
Pedestrian priority	PP1	4.19	4.14	4.12	4.23	4.12	4.15	**4.22***	**3.92***
Attitudes towards speed limits	SA1	3.51	3.80	3.70	3.97	3.64	3.79	3.77	3.71
	SA2	3.52	3.49	3.44	3.73	3.47	3.51	3.45	3.64
Risk-taking attitudes	RT1	**2.52***	**2.11***	**2.07***	**2.58***	**2.80***	**1.95***	**1.95***	**2.82***
	RT2	**2.88***	**2.19***	**2.17***	**2.79***	**2.81***	**2.11***	**2.04***	**3.01***
	RT3	**2.37***	**1.99***	**1.95***	**2.43***	**2.49***	**1.89***	**1.82***	**2.71***
	RT4	2.68	2.53	**2.45***	**2.98***	**2.89***	**2.44***	**2.37***	**3.09***
Risk awareness	RA1	**4.11***	**4.59***	4.53	4.46	4.39	4.56	**4.63***	**4.21***
	RA2	**3.96***	**4.38***	4.30	4.39	**4.15***	**4.38***	**4.43***	**3.98***
Frustration while riding	FR1	**2.99***	**2.38***	**2.36***	**2.93***	**2.93***	**2.31***	**2.27***	**3.05***
	FR2	**3.23***	**2.66***	**2.66***	**3.07***	**3.15***	**2.60***	**2.59***	**3.17***
	FR3	**2.92***	**2.30***	**2.26***	**2.91***	**2.90***	**2.21***	**2.20***	**2.95***
Risk prediction	RP1	**3.32***	**3.65***	3.61	3.56	3.50	3.63	**3.69***	**3.33***
	RP2	**3.36***	**3.72***	3.69	3.60	**3.54***	**3.72***	**3.76***	**3.42***
	RP3	**3.32***	**3.66***	3.63	3.53	**3.47***	**3.66***	**3.71***	**3.33***
Risk avoidance	RD1	**2.82***	**3.13***	**3.13***	**2.93***	3.16	3.06	3.13	2.98
	RD2	**3.09***	**3.47***	**3.45***	**3.26***	3.34	3.43	**3.51***	**3.11***
Violation of traffic rules	VT1	2.35	2.15	2.15	2.30	**2.38***	**2.11***	**2.05***	**2.56***
	VT2	**1.96***	**1.68***	**1.67***	**1.94***	**2.01***	**1.62***	**1.57***	**2.17***
	VT3	**2.01***	**1.76***	**1.76***	**1.97***	**2.15***	**1.67***	**1.65***	**2.22***
Distracted riding	DR1	**1.93***	**1.68***	**1.66***	**1.97***	**1.98***	**1.63***	**1.55***	**2.21***
	DR2	**2.13***	**1.80***	1.81	2.00	**2.17***	**1.73***	**1.70***	**2.28***

Accident involvement emerged as a critical factor influencing risk-taking attitudes and behaviors, consistent with prior research on Malaysian motorcyclists (Borhan et al., 2018). Experienced riders demonstrated better risk awareness and hazard perception abilities, while novice riders (with less than three years of experience) were more prone to risky behaviors. Participants in the HVN program exhibited more positive attitudes toward road safety, with reduced tendencies for risk-taking, violations, and distracted riding compared to non-participants. However, the program did not show significant effects on improving safer attitudes and behaviors, such as risk awareness and prediction.

Although experienced riders generally performed better across most items, no significant differences were observed in compliance with avoiding drinking and driving (item RT4) or refraining from riding on sidewalks (item VT1), both of which were critical factors for accident involvement. Previous research supports that reducing alcohol-related violations significantly decreases traffic risks for Vietnamese motorcyclists (Bui, Saadi, & Cools, 2020). The HVN program had a positive impact on reducing drinking and driving but showed no significant effect on curbing sidewalk riding. Given that riding on sidewalks is a common practice in many motorcycle-dependent regions, particularly in suburban areas, this behavior poses risks to pedestrian safety and causes significant damage to walkways. These findings provide actionable insights for improving road safety interventions.

Altruism was found to be a significant determinant of attitudes toward safety awareness and behavioral factors. Although altruistic motivations for safe riding are rarely studied, relevant discussions exist in prior research (Wong, Chung, & Huang, 2010; Chen, 2009). Notably, altruism was the only factor showing a significant difference in prioritizing pedestrians. However, no significant differences were observed in attitudes toward speed limits across all groups.

Effect of Education on Risk Prevention

The study indicated that experienced riders tend to have better road safety knowledge. However, the effectiveness of rider training programs in preventing accidents among experienced riders appears to be limited. Among novice users participating in the training program, the accident rate was 38%, representing a 12% reduction compared to those with similar riding experience who did not participate in training. In contrast, experienced riders showed almost no difference in accident rates between participants and non-participants. Specifically, 25% of HVN participants reported experiencing accidents, compared to 23% of non-participants over the past year. Regarding personal traits, altruism emerged as the most significant factor influencing motorcyclists' safe riding behaviors.

Structural Relationships among Attitudes and Behaviors

As shown in **Figure 4.3**, the structural relationship between accidents and behaviors was further analyzed to evaluate the effectiveness of the HVN safe riding program, particularly in enhancing riders' risk awareness and risk prediction abilities—critical components for fostering positive attitudes toward safer behaviors. The causality analysis revealed a direct relationship between risk awareness and risk prediction, where increased risk awareness led to improved risk prediction. While no direct effect of risk prediction on accident reduction was observed, an indirect effect was identified: heightened risk awareness reduced risk-taking behavior, which subsequently decreased accident rates. Notably, participants who reported improved safety awareness after participating in traffic safety activities also showed a significant increase in risk awareness. This highlights that motorcyclists' enhanced risk awareness is largely driven by a stronger recognition of the need to protect life.

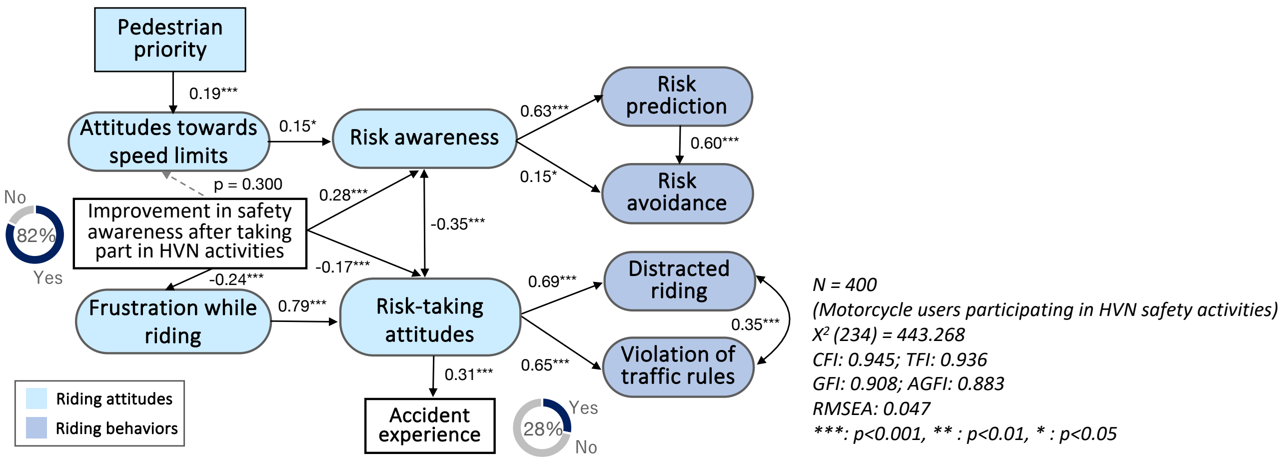

Figure 4.3 Causality analysis among motorcyclists' riding attitudes, behaviors, educational effect, and accident experience

Furthermore, the social impact analysis (**Figure 4.4**) showed that rider training positively influenced participants by enhancing their confidence, joy, and comfort while riding, as well as their sense of freedom in mobility. Importantly, an increased awareness of safety and the value of life contributed to fostering altruistic motivations, enabling motorcyclists to consider the perspectives of pedestrians and car drivers. These results emphasize the need to instill moral responsibility in motorcyclists and offer valuable insights for improving traffic safety education programs.

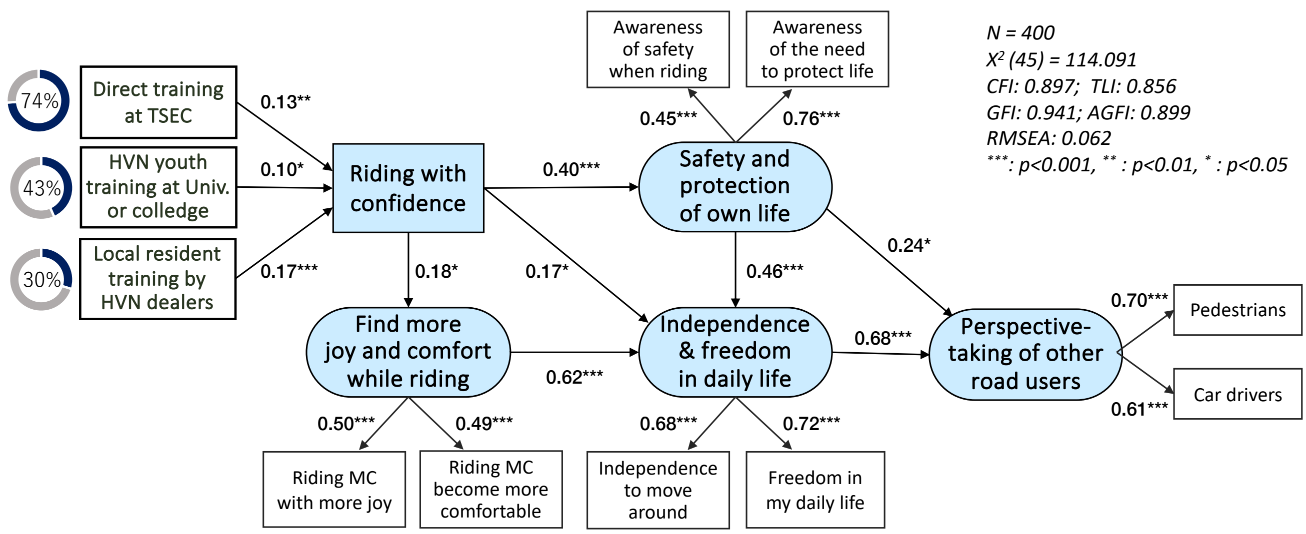

Figure 4.4 Structural relationship to describe the combination of factors contributing to motorcyclist's wellbeing and quality of life.

4.2.5 Critical Reflections on Prior Work

While the results successfully address specific issues within the existing road safety training program, the methodology highlights limitations in its adaptability to other regions or dynamic contexts. Addressing these challenges requires a deeper understanding of the interplay between risk perception and behavior, which is essential for identifying the strengths and shortcomings of current training approaches.

In the context of traffic safety, extensive research has explored cross-cultural comparisons of risk perception. These studies, often based on self-reported surveys, examine the relationships between perception, attitudes, and risky behaviors. Empirical evidence suggests that cultural differences significantly influence risk tolerance, with some countries displaying a greater willingness to engage in risky behavior in both traffic and general contexts (Nordfjærn, Jørgensen, & Rundmo, 2011). However, these cultural variations mean that survey items used to predict behavior in one context may not hold the same predictive value in another (Lund & Rundmo, 2009). Despite strong evidence linking risk perception to risky behavior, there is no universally defined construct to standardize questionnaire development for cross-cultural adaptability and meaningful comparison. This gap in the framework limits the ability to evaluate risk perception effectively across diverse cultural contexts.

To overcome these limitations, evaluations must go beyond outcome-focused metrics, such as reduced accidents or fatalities, and investigate the underlying mechanisms driving risk perception and behavior formation. Incorporating frameworks such as psychometrics and cultural theory offers a robust approach to understanding how individuals perceive and respond to risks within their cultural contexts. This perspective not only enhances insights into behavioral drivers but also supports the creation of culturally adaptable and more effective safety interventions, ultimately increasing the scalability and impact of education programs.

4.3 Psychometrics and Cultural Factors in Behavior Formation

Risk perception often diverges from objective facts because it is shaped by various subjective factors, such as affective influences, cognitive biases, contextual elements, and individual characteristics (Godovykh, Pizam, & Bahja, 2021). Psychological research on risk perception seeks to understand how people process information. One influential framework that incorporates both cognitive and emotional dimensions of risk perception is the psychometric paradigm, developed by Slovic and his colleagues (Slovic, 1987). The cognitive dimension relates to individuals' understanding of risks, particularly their perceived severity, while the affective dimension refers to ***emotional perception***, such as fear or anxiety.

This study builds on the psychometric paradigm by incorporating the concept of ***efficacy perception***—the belief in one's ability to manage or mitigate risks—and exploring its role in shaping risk perception and behavior. If individuals perceive a risk as less severe and believe they can control it (i.e., high self-efficacy), they are more likely to view the risk as less threatening and may be inclined to engage in risk-taking behaviors (Wilde, 1994). This relationship is also explored in other theories, such as perceived behavioral control in the Theory of Planned Behavior and self-efficacy in health behavior models.

Social influences may also contribute to the formation of risk perception. Cultural theory, particularly highlighted through the work of anthropologist Mary Douglas, argues that people's views on risk are significantly influenced by their social groups. This theory posits that societal norms and values, deeply ingrained through cultural influences, shape individuals' perceptions and behaviors regarding what is expected risky or acceptable. These cultural norms not only dictate behaviors but are also crucial in understanding societal conflicts over risk perception.

Building on this foundation, risky behaviors are often seen as the result of decision-making processes that have become automatic and routine due to past experiences. These experiences can lead to the formation of habits, where behaviors, when repeatedly performed in similar contexts, become automatic, as noted by Verplanken (2006). These habituated actions are often triggered by contextual factors, which play a significant role in shaping the intentions behind risky behaviors. An empirical study by Stefanova et al. (2018) underscores this interaction, demonstrating how pedestrians' perceptions of risk and their intentions to engage in risky crossing behaviors are influenced by the surrounding context. Their research found that past unsafe behaviors (i.e., habits), descriptive norms (i.e., social/cultural influence), and the perceived risk of involvement in a crash are consistent predictors of the likelihood to engage in risky behaviors across various scenarios.

This study proposes ***contextual factors*** and ***habituated actions*** as key determinants of risk perception. Contextual factors refer to the specific conditions or environments in which individuals assess and respond to risks, such as traffic or road conditions while driving. These factors, alongside culturally ingrained norms, contribute to habituated actions—routines or behaviors that individuals regularly perform, often without conscious thought. For example, in cultures where risky behaviors like driving without a helmet are normalized, these actions may become habitual, leading individuals to perceive such risks as less significant.

Thus, cultural norms and contextual cues collectively trigger these habituated behaviors, leading to patterns of risk-taking such as traffic violations. Understanding these interactions is crucial for explaining the persistence of such behaviors and can inform targeted interventions to enhance road safety. **Figure 4.5** illustrates the proposed factors that determine the formulation of risk perception, integrating cultural theory with contextual and habitual factors to provide a comprehensive understanding of risk-taking behavior in traffic environments.

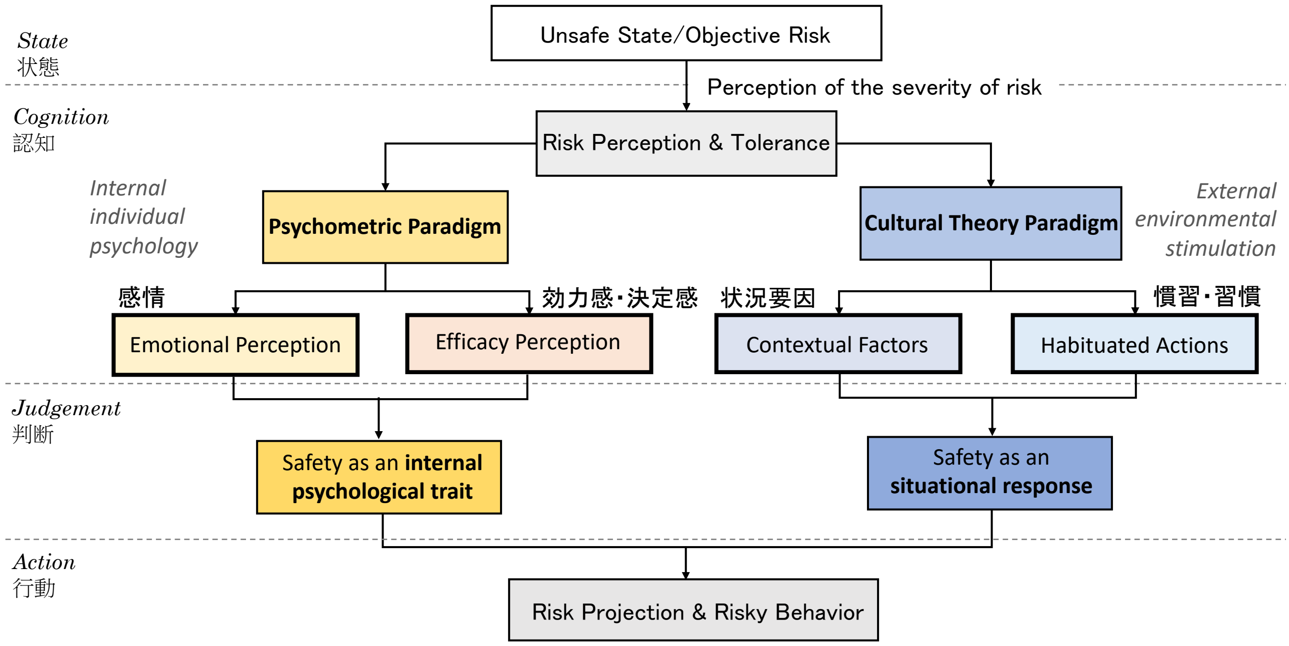

Figure 4.5 Factors involved in the formation of risk perception.

The interactions among proposed factors are explore from the perspective of Stimuli-Organism-Response (SOR) model (Vieira, 2013) (**Figure 4.6**). The SOR model essentially states that behavior is a function of continuous interactions between the external environment and internal psychological processes. It highlights that responses are not direct reactions to stimuli but are mediated by the internal state of the organism, providing a deeper understanding of why individuals behave differently even under similar external conditions. In the study context, risk perception and behavior are supposed to been influenced by both external (contextual factors and habituated actions) and internal (emotional and efficacy perception) factors. The stimulus provided by cultural and contextual elements leads to internal processing (emotional responses and efficacy beliefs), which then manifests in behaviors such as risk projection, rule violations, and ultimately accident risks.

By studying the correlations between these four factors, this research aims to understand how different dimensions—contextual, habitual, emotional, and psychological—interact to shape risky behaviors in traffic settings. A more concrete hypothesized model is presented in **Figure 4.7**. The model integrates key components underlying the causality proposed by Nola Pender's Health Promotion Model (Pender, Murdaugh & Parsons, 2006) to explain how individual characteristics interact with external influences to shape behvaior-specifc cognition and affect behavioral outcomes. In the study context, drivers' cognitive and emotional processing shape their experiential value, which mediate cognitive effects on contextual and habituated actions, thus formatting behavioral response like projection and violation. The proposed model offers a comprehensive view of how external stimuli are filtered through psychological mechanisms to produce observable behaviors, particularly in the context of traffic safety.

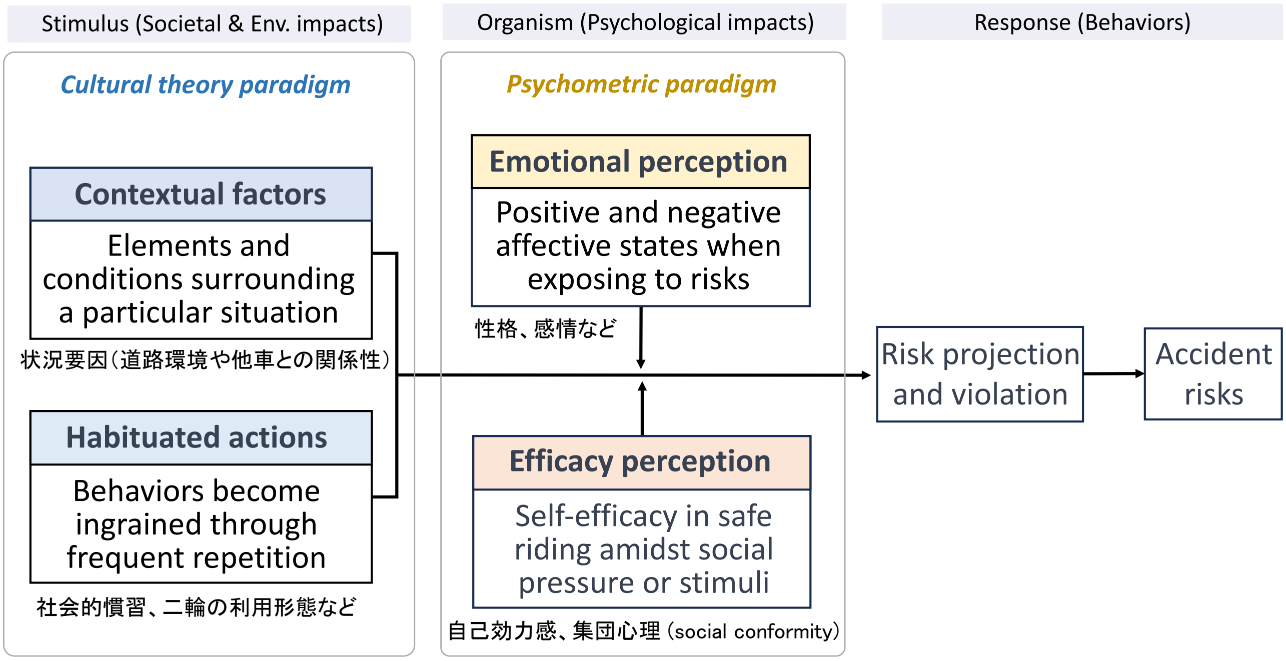

Figure 4.6 Psychological and social impacts on risk perception: A causal relationship overview based on the stimulus-organism-response model.

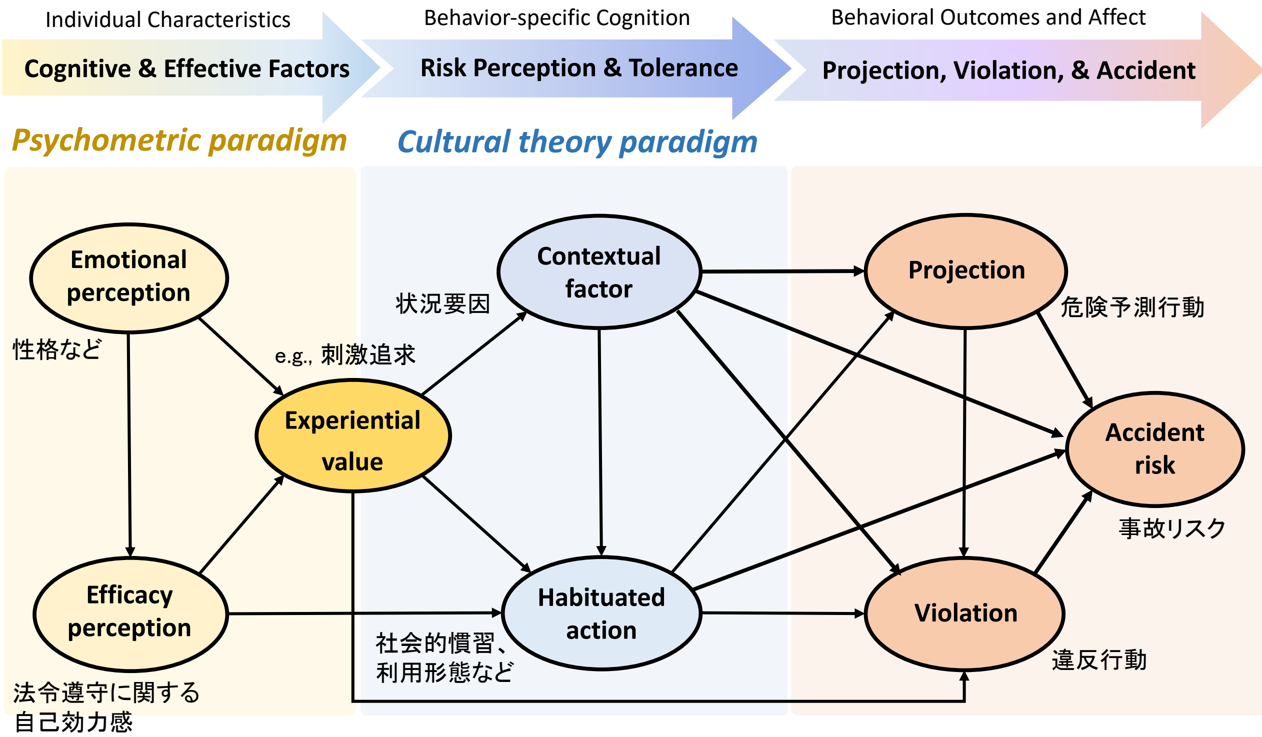

Figure 4.7 Hypothesized model.

4.4 Materials and Methods

4.4.1 Data Collection

To investigate the roles of psychometrics and cultural factors in shaping motorcyclists' behaviors, a self-administered questionnaire survey was conducted in Bangkok from October 12 to November 6, 2023. To ensure regional diversity, the survey was managed by a market research agency, which utilized online methods to reach participants across the nation. Based on prior studies and evidence from previous work (Global Road Safety Facilities, 2021; Chou et al., 2022), the age group of 18–30 years was identified as the most significant demographic for experiencing accidents. Consequently, the survey targeted individuals aged 18–30 who ride motorcycles at least once a week. A total of 1,219 valid responses were collected for this study. **Table 4.2** provides the sample profile.

Male and female respondents were nearly evenly split, accounting for 50.1% and 49.9% of the sample, respectively. Of the total respondents, 476 (39.0%) were from the Greater Bangkok area. The majority of respondents used motorcycles as their primary mode of daily transportation, with 77.5% riding more than five days per week, followed by 15.4% riding three to four days per week. Regarding licensing, 80.0% of respondents currently held a valid motorcycle license, while 16.5% reported never having obtained one. Additionally, approximately 55% of respondents had attended a driving school, while the remaining had not.

Table 4.2 Sample profile.

Characteristics	Sample size (n=1,219)	Percentage (%)
Gender		
Male	611	50.1
Female	608	49.9
Residential region		
Great Bangkok	476	39.0
Central	182	14.9
Northeast	222	18.2
North	180	14.8
South	159	13.0
Motorcycle driving frequency		
More than 5 days per week	945	77.5
3-4 days per week	188	15.4
1-2 days per week	86	7.1
Less than once per week	0	0.0
Motorcycle driving license		

Currently held	975	80.0
Previously held	43	3.5
Never held	201	16.5
Motorcycle riding school attendance		
Attended a government-certified driving school	647	53.1
Attended a non-certified driving school	22	1.8
Did not attend any driving school	549	45.0
Do not remember	1	0.1

4.4.2 Survey Design and Measures

The questionnaire consisted of three sections. The first section gathered demographic information, including gender, residential region, motorcycle driving frequency, license, accident history, and participation in traffic safety education and training, such as attendance at a driving school. Specifically, respondents were asked about their accident experiences through questions such as: “In your life, how many motorcycle accidents have you been injured in?” and “What is your most serious motorcycle accident or near-miss in the past year?”

The second section comprised three sets of items, evaluated using a five-point Likert scale (5 = strongly agree, 1 = strongly disagree). This section aimed to assess psychometric attributes, cultural factors, and driving behaviors. The psychometric attributes included three constructs: emotional perception (3 items), efficacy perception (3 items), and experiential value (3 items). Cultural factors were measured through two constructs: contextual factors (3 items) and habituated action (3 items). Driving behavior was assessed through two constructs: projection (4 items) and violation (3 items).

4.4.3 Data Analysis

Descriptive statistics were initially performed to summarize the basic features of the data. An independent sample t-test was conducted to compare the performance between groups. Before performing the t-test, Levene’s test (Levene, 1960) was applied to assess the homogeneity of variances. Insignificant values from Levene’s test confirmed that the data were suitable for further analysis.

This study employed Structural Equation Modeling (SEM) with maximum likelihood estimation to verify the hypotheses. Before proceeding with the analysis of model specification and correlation, scale validation was conducted. The data analysis followed a two-stage approach. In the first stage, confirmatory factor analysis (CFA) was used to validate the measurement model. In the second stage, the hypothesized structural model was tested empirically using SEM.

4.5 Results and Discussions

4.5.1 Descriptive Statistics

Table 4.3 shows the descriptive statistics, including item means and standard deviation of each construct in the hypothesized model.

Table 4.3 Descriptive statistics.

Constructs and items (strongly agree = 5, strongly disagree = 1)		Mean	S.D.
Emotional perception (EP)			
EP1	I seek out thrill and achievement by engaging in risky activities.	2.68	1.325
EP2	It is difficult for me to suppress my desires for things I want to do.	3.13	1.121
EP3	I put the troubles aside and put fun first.	2.64	1.148
Efficacy perception (EF)*			
EF1	It is acceptable to exceed speed limits as long as I don't feel any immediate danger.	2.69	1.351
EF2	I do not want to wear a helmet at night because I think the police will not catch me.	2.46	1.291
EF3	If I feel sober after drinking alcohol, I think I can drive without impairment	2.37	1.325
Experiential value (EV)			
EV1	At night, I ride on the shoulder of a main road at the same speed as the traffic in the lane.	2.18	1.179
EV2	I do daring high-speed driving or stunt driving because it gives me a sense of thrill and accomplishment.	2.04	1.130
EV3	I ride a short distance after having a bottle of beer.	1.84	1.100
Contextual factor (CF)			
CF1	On congested roads, I frequently change lanes to overtake vehicles.	2.66	1.077
CF2	I get frustrated because I can't pass the slow car in front of me.	2.61	1.108
CF3	As soon as I see a slower car in front of me, I immediately move to the opposite lane to overtake it.	3.05	1.029
Habituated action (HA)			
HA1	I drive while fatigued or feeling drowsy.	2.17	1.111
HA2	I use my smartphone with one hand while driving when receiving a message or a call.	2.28	1.124
HA3	I don't stop at a stop sign intersection if there are no cars.	2.43	1.236
Projection (PR)			
PR1	I observe the surrounding vehicles at intersections and anticipate their behavior and intentions.	3.83	1.016
PR2	When I see a car from a side street, I imagine how I will avoid it if it pulls out in front of me.	3.46	1.084
PR3	I give way to other vehicles if our paths overlap when changing lanes.	3.61	0.991

PR4	I actively adjust my position and speed to make sure I am prepared for any sudden braking or cut-in by the car ahead.	3.71	1.071
Violation (VI)			
VI1	I change lanes without checking my mirrors and blind spots.	1.95	1.097
VI2	I drive in the opposite lane or on the sidewalk to bypass the traffic.	2.05	1.174
VI3	I don't wear a helmet when riding short distances within residential areas.	3.27	1.238
Accident risk (AR)			
AR1	Accident experience in the past year. (binary)	0.54	-
AR2	Number of accidents in your life where you were injured and went to the hospital for treatment	1.83	1.310
AR3	Number of accidents in your life where you were injured but did not go to the hospital for treatment	2.21	1.562

Note: *: Reverse question (strongly degree = 1, strongly disagree = 5)

4.5.2 Riding experience, accidents, and effect of motorcycle rider training

In our previous work, experienced riders demonstrated better performance in road safety measures. However, considering the limitation of the self-administered survey, where experienced riders may have scored higher due to their superior knowledge, we further examined whether this better performance reflected in accident prevention. **Table 4.4** presents a cross-tabulation of gender, driving experience, and accident rates over the past year.

It is important to note that this analysis excluded drivers working in professional roles, such as motorcycle taxi operators or delivery personnel, as their higher exposure to accident risks could introduce additional biases, making comparisons less reliable.

Table 4.4 Cross-tabulation of gender, driving experience, and accident rate in the past year.

	Male						**Female**						Total	
License	No	n	Yes	n	Sum	n	No	n	Yes	n	Sum.	n	Ave.	n
Less than 5 years	**4.1%**	49	**4.3%**	141	4.2%	190	**7.1%**	42	**6.8%**	176	6.9%	218	5.6%	408
5 years or more	**5.4%**	56	**9.0%**	310	8.5%	366	**16.7%**	78	**5.1%**	272	7.7%	350	8.1%	716
Total	**4.8%**	105	**7.5%**	451	7.0%	556	**13.3%**	120	**5.8%**	448	7.4%	568	7.2%	1124

The estimated results revealed that experienced drivers (8.1%) had a higher accident rate than novice drivers (5.6%) in the past year, which contrasts with findings from previous research conducted in Vietnam. A comparison across genders showed that experienced male drivers exhibited a higher accident risk, while no significant difference was observed among female drivers.

Regarding the effect of license acquisition, the accident rate among female drivers without a license was 13.3%, compared to 5.8% for licensed female drivers. This effect was particularly pronounced among experienced female drivers, whose accident rate decreased significantly from 16.7% to 5.1% with a license. In contrast, male drivers showed different trends. There was no significant difference in accident rates among novice male drivers, while experienced male drivers with a license had a higher accident rate (9.0%) compared to those without a license (5.4%), indicating limited effectiveness of licensing for this group.

The two-way ANOVA results provided statistical evidence of a significant interaction effect between gender and license acquisition on accident rates, $F = 7.493$, $p = 0.006$. This finding suggests that the impact of license acquisition varies significantly by gender.

The results suggest that experienced riders, despite their better performance in road safety knowledge, may not always exhibit lower accident rates. This highlights the complexity of accident causation, which likely extends beyond driving experience and knowledge alone. To fully understand the factors contributing to accidents, it is essential to investigate the underlying reasons that influence behavior.

4.5.3 Measurement model

A preliminary CFA was conducted, during which one item (V3) was eliminated to improve reliability and reduce measurement error, as its standardized factor loading did not meet the minimum criterion of 0.5 (Hair, 2009). According to Hair (2009), the convergent validity of CFA results is assessed through item reliability (e.g., standardized factor loadings and Cronbach's α), composite reliability (CR), and average variance extracted (AVE).

The estimated model demonstrated good fit indices: CFI = 0.94, TLI = 0.93, RMSEA = 0.047, GFI = 0.95, and AGFI = 0.93. As presented in **Table 4.5**, standardized factor loadings ranged from 0.53 to 0.82, meeting the required threshold of 0.50. Both Cronbach's α and CR values for all latent constructs exceeded the recommended level of 0.70.

The construct "Accident Risk," measured by state data (e.g., number of accidents experienced) rather than a Likert scale, was excluded from item validity testing. Discriminant validity was confirmed using Fornell and Larcker's (1981) criterion, where AVE values above 0.40 are acceptable if CR exceeds 0.70. These results support the reliability and validity of the model.

Table 4.5 CFA results.

Construct	Item	Standard factor loading	Standard error	Cronbach's α	CR	AVE
Emotional perception	EP1	0.75	0.038	0.72	0.73	0.48
	EP2	0.63	0.033			
	EP3	0.67	0.034			
Efficacy perception	EF1	0.67	0.039	0.75	0.75	0.50
	EF2	0.75	0.036			
	EF3	0.71	0.037			
Experiential value	EV1	0.67	0.033	0.77	0.78	0.54
	EV2	0.82	0.029			
	EV3	0.71	0.030			
Contextual factor	CF1	0.74	0.030	0.72	0.72	0.47
	CF2	0.67	0.032			
	CF3	0.63	0.030			
Habituated factor	HF1	0.77	0.029	0.71	0.73	0.47
	HF2	0.75	0.030			
	HF3	0.55	0.035			
Projection	PR1	0.70	0.030	0.73	0.73	0.41
	PR2	0.64	0.032			
	PR3	0.60	0.030			
	PR4	0.62	0.032			
Violation	VI1	0.76	0.030	0.70	0.70	0.54
	VI2	0.71	0.032			

4.5.4 Structural Model and Hypotheses Tests

The hypothesized structural model was estimated to evaluate the relationships between constructs. The model demonstrated an acceptable fit to the sample data, as indicated by the goodness-of-fit indices: CFI = 0.94, TLI = 0.92, GFI = 0.94, AGFI = 0.93, and RMSEA = 0.048. Figure 4.8 presents the estimated model, including standardized path coefficients and significance levels.

Most of the hypothesized relationships in the model were empirically supported, with the exception of the effects of contextual factors on projection and violations, which were not significant. Notably, accident risk was directly influenced by habituated actions, rather than by other constructs in the model.

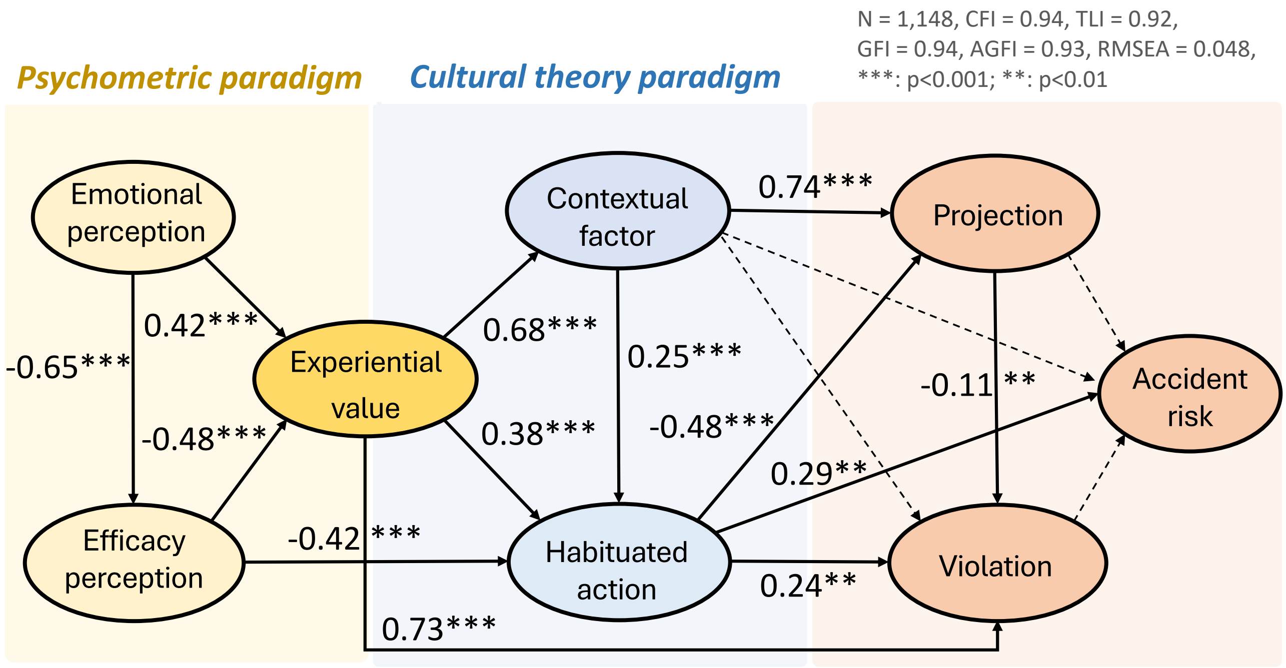

Figure 4.8 Estimated model.

Emotional perception had a significant negative effect on drivers' efficacy to follow traffic rules (β = -0.65, $p < 0.001$) and a positive effect on experiential value, which reflects the pursuit of exciting experiences (β = 0.42, $p < 0.001$). Drivers with stronger emotional responses may feel less confident or capable of adhering to traffic rules, possibly due to heightened impulsivity or emotional distractions. At the same time, these drivers are more likely to seek thrilling experiences, often associated with risky behaviors.

In contrast, efficacy in following rules plays a crucial role in reducing risky behaviors. It significantly decreases both experiential value (β = -0.48, $p < 0.001$) and habituated risky actions (β = -0.38, $p < 0.001$). A stronger sense of efficacy discourages high-risk pursuits and promotes adherence to safe practices, reducing the likelihood of developing habitual risky behaviors. However, an alternative perspective by Wilde (1994) suggests that individuals who feel highly efficacious in controlling risks—whether due to safety measures or personal skill—may paradoxically engage in more risk-taking behaviors. This implies that increased efficacy could, in some cases, lead to risk compensation rather than risk mitigation.

Drivers' pursuit of excitement (i.e., experiential value) had significant positive effects on contextual factors (β = 0.68, $p < 0.001$) and habituated actions (β = 0.38, $p < 0.001$). This suggests that individuals seeking excitement are more likely to develop higher risk tolerance and engage in habitual risky behaviors. Such thrill-seeking tendencies influence how drivers perceive and interact with their environment, further reinforcing risky behaviors. This result is supported by previous research. Slovic et al. (1982) found that the greater people perceived a benefit, the greater risk tolerance. If a person derived pleasure from using a product, people tended to judge its benefits as high and its risks as low.

Notably, habituated risky actions negatively affected drivers' ability to project risky scenarios ($\beta = -0.48$, $p < 0.001$), while having positive effects on violations ($\beta = 0.24$, $p < 0.001$) and accident risk ($\beta = 0.29$, $p < 0.001$). Habitual risky behaviors reduce the capacity to anticipate or foresee potential dangers, likely due to desensitization to risks. They also increase the likelihood of committing traffic violations, which directly contributes to a higher risk of accidents.

This analysis highlights the complex interplay between emotional perception, efficacy, thrill-seeking tendencies, and habitual behaviors, offering insights for designing interventions to reduce risky behaviors and improve road safety.

4.6 Conclusions

This study attempts to enhance motorcycle safety by blending environmental specificities (Urbs) and cultural insights (Civitas), aiming to foster safer and more sustainable mobility practices across diverse urban landscapes. Traffic injuries remain a leading cause of mortality in many developing countries, creating significant barriers to sustainability and raising concerns about introducing small-format mobility, even in developed urban areas. Despite the critical importance of accident analysis and prevention, data collection systems in Southeast Asia, including Vietnam and Thailand, continue to face inconsistencies and underreporting issues (World Health Organization, 2016). This highlights the need for more effective tools to assess initiatives and promote safer driving practices.

The Motorcycle Rider Behavior Questionnaire (MRBQ) has been increasingly used for this purpose in both developing countries (e.g., Uttra et al., 2020) and developed nations such as the UK (Elliott et al., 2007) and Australia (Sakashita et al., 2014). However, existing questionnaires often lack universally defined constructs, contain excessive items, and rely on exploratory methods, limiting their adaptability for cross-cultural comparisons and standardized evaluations. To address these gaps, this study incorporates psychometrics and cultural theory into a structural correlated model, offering a more comprehensive and interpretable framework for understanding the behavioral formation of motorcyclists. The proposed model identifies key factors contributing to accidents and provides a foundation for developing standardized questionnaires to enable cross-cultural adaptability and meaningful comparisons. This approach enhances the evaluation of risk perception and driving behaviors, supporting the creation of targeted and impactful safety interventions.

Building on the author's previous work on motorcycle safety culture in Vietnam, this study extends the analysis by focusing on behavioral formation from psychometric, cultural, and habituated perspectives in Thailand. The findings reinforce earlier research, highlighting the necessity of combining on-road experience with progressive training and education to effectively promote motorcycle safety (Chou et al., 2022; Blackman & Haworth, 2013). Moreover, the rapid increase in motorcycle ownership has significantly impacted urban forms in ASEAN countries, creating challenges for livable cities. While motorcycle-dominated traffic complicates urban development, safety initiatives help reduce accident risks, improve motorcyclists' well-being, and create safer, more pleasant traffic environments.

The findings of this study highlight the significant role of cross-sector collaborative education programs in promoting a sustainable safety culture. In Vietnam, such programs—integrating partnerships among stakeholders—have effectively engaged society by providing textbooks, helmets, and media campaigns to the new generation, fostering safety awareness and moral responsibility. The impact of these initiatives extends beyond individual behavioral changes, influencing communities and society at large. This process embodies a transition from individual safe riding practices to the socialization of a sustainable motorcycle culture through co-creation among citizens, communities, and institutions.

However, in Thailand, where a consistent and well-recognized education content is lacking, the extent to which rider training and education programs can compensate for limited experience remains unclear. The study also identified habituated actions, such as driving while fatigued, using a smartphone while driving, or ignoring traffic signs, as the most significant contributors to accidents. These findings underscore the need for standardized evaluation tools and targeted interventions to address habitual risky behaviors effectively in this context.

The road safety crisis extends beyond individual motorcyclists, impacting all traffic participants and placing significant strain on national economies. Studies on the economic costs and benefits of road safety interventions emphasize that ensuring mobility safety is essential for achieving broader societal and environmental welfare goals (Waters, Hyder, & Phillips, 2014). The rise of electric personal mobility, including electric two-wheelers, presents an opportunity for sustainable solutions. Advances in energy charging infrastructure have accelerated the adoption of electric vehicles, providing an irreplaceable sense of freedom while addressing environmental and safety concerns. To enhance livability and efficiency, cities must prioritize citizen well-being by implementing safer and more efficient mobility systems. By fostering sustainable motorcycle cultures through collaborative safety initiatives, urban areas can make meaningful progress toward their livability and sustainability objectives.

5 Developing Theories of Change for Sustained Intention to Reduce Private Car Use

Summary: This chapter explores the intersection of Civitas—emphasizing mobility culture and the contextual factors influencing private vehicle use—and Cyber—focusing on the provision of innovative mobility services—to advance sustainable transport development. This analysis is particularly relevant as cities seek to reduce reliance on private cars by encouraging the adoption of more sustainable, community-oriented travel modes.

The chapter targeted a community-based electric ride-sharing pilot project introduced in Bangkok, Thailand, designed to shift resident behaviors from private car use to more eco-friendly modes. Integrating the Theory of Planned Behavior (TPB), Technology Acceptance Model (TAM), and goal-framing theory, the study meticulously traces the cognitive development from initial trial use to sustained behavior change in adopting these alternative travel modes.

Data collected from 101 valid responses from service users reveal that travel-related self-efficacy plays a crucial role in encouraging the continued use of promoted services by aligning eudaimonic and normative goals during the intervention. Multi-group analysis highlighted the moderating effects of transport mode preferences on the hypotheses, indicating that users' travel-related self-efficacy positively affected their intentions to sustain behavioral change. However, the study also notes a significant decline in users' willingness to pay for the service, highlighting the necessity for affordable mobility options to maintain self-efficacy in daily transport.

The study proposes an integrated model that elucidates how interventions can lead to developmental changes in behavior, particularly focusing on the role of self-efficacy in fostering enduring behavior change within the context of a community-based electric ride-sharing service. By examining the relationship between self-efficacy and sustained behavioral intentions, this chapter provides deeper insights into the mechanisms driving long-term user engagement and commitment, underpinned by both cultural and technological dimensions of urban mobility.

This chapter is a version of the following publication: Chou, C. C., Iamtrakul, P., Yoh, K., Miyata, M., & Doi, K. (2024). Determining the role of self-efficacy in sustained behavior change: An empirical study on intention to use community-based electric ride-sharing. Transportation Research Part A: Policy and Practice, 179, 103921.

5.1 Introduction

Developing countries are experiencing rapid economic growth, outpacing the mature economies of developed nations. In Southeast Asia, this growth has fueled a surge in motorization, particularly in major cities (United Nations, 2020). However, infrastructure and traffic management have struggled to keep up, leading to severe traffic congestion and parking shortages. As a result, citizens face long commutes, reduced economic productivity, and increased air pollution (The World Bank, 2022). Most cities in the region, except for Singapore, have not prioritized developing well-connected public transport networks. A significant issue is the "first and last-mile" problem—the lack of seamless connectivity between metro stations and travelers' origins or destinations—causing widespread dissatisfaction with public transport (Dunn, 2019).

Against the background, private cars are the preferred mode of travel due to their reliability and utility for daily mobility. However, car ownership is influenced not only by transport infrastructure but also by personal preferences, cultural norms, and symbolic values, such as social status, and affective values, like driving pleasure (Le Loo et al., 2015; Steg, 2003). Although convenient public transport can reduce the demand for car ownership, the unique advantages offered by private cars often sustain their appeal.

Ride-sharing has emerged as a promising solution to address these challenges, offering accessible, safe, and affordable mobility while curbing emissions (International Transport Forum, 2022). Introduced in Southeast Asia in 2013, ride-sharing has transformed urban transport across the region. By 2021, the industry was valued at approximately USD 13 billion. Companies like Grab and Gojek dominate the market, with Grab serving 187 million users across eight countries and Gojek achieving 190 million downloads and 38 million active users monthly (Consumer News and Business Channel, 2020; Rai & Kshirsagar, 2022). These platforms offer not only ride-hailing but also food and parcel delivery services. Alongside these giants, numerous local ride-hailing applications cater to the region's dynamic travel demands (Chalermpong et al., 2023). However, while ride-sharing addresses mobility needs, it also brings risks, including road safety concerns, traffic congestion, and issues related to liability (Icasiano & Taeihagh, 2021).

In this context, the Smart Small Vehicle Service (SSVS) has been introduced in Bangkok, Thailand since December 2021 as a part of the research activity of the SATREPS Program (JST/JICA Science and Technology Research Partnership for Sustainable Development) (Japan International Cooperation Agency [JICA], 2018). The SSVS pilot project aims to reduce reliance on private vehicles and promote sustainable transport to alleviate traffic congestion and foster a low-carbon society. This study focuses on evaluating the viability and public receptiveness of the SSVS as a novel community-based ride-sharing initiative. By utilizing compact electric vehicles, the SSVS seeks to enhance public transport accessibility, support sustainable neighborhood development, and contribute to the broader goal of achieving sustainable urban mobility.

5.1.1 Community-Based Mobility Services

Car sharing provides a sustainable urban mobility alternative (Esfandabadi, Diana, & Zanetti, 2022), with significant potential to reduce environmental impacts. For instance, one-way car sharing can remove up to 11 cars from the streets and cut greenhouse gas emissions by approximately 13 metric tons annually (Martin & Shaheen, 2016). In recent years, community-based car sharing has gained attention, particularly in areas without commercial operators. Unlike traditional car sharing, community-based initiatives are locally organized and typically non-commercial (Dorner & Berger, 2018), offering an effective solution for underserved regions.

Electric car sharing further enhances these benefits by combining economic and environmental advantages. However, the high cost of electric vehicles (EVs)—averaging $18,000 more than conventional vehicles as of July 2022 (Kelley Blue Book, 2022)—makes them inaccessible for many. Shared EVs address this challenge by providing a cost-effective mobility option for the general public. Nevertheless, shared mobility also faces challenges, such as ensuring equitable access and addressing criticisms that it favors those willing or able to drive (Hartl & Hofmann, 2022; Dorner & Berger, 2018). Overcoming these issues is crucial for the sustainable adoption of shared vehicles within communities.

Combining car sharing and ride-sharing is another promising concept, as trust plays a key role in sharing vehicles and rides (Dorner & Berger, 2018). In such arrangements, shared cars can be driven by either a volunteer or a hired driver. Research has explored tools to support ride-sharing practices within car sharing communities, especially in rural areas where car dependency is high (Dorner & Berger, 2018). A study in rural Austria and Germany assessed community members' willingness to serve as ride-sharing drivers. Similarly, a recent study introduced an optimization model for community-based trip sharing in urban settings, using community structures and commuting patterns to optimize car and ride-sharing (Hasan et al., 2018). This model reduced daily car usage by up to 44%. Further research has examined the role of autonomous vehicles in enhancing community-based trip sharing (Hasan & Van Hentenryck, 2021).

Community-based mobility, whether through EVs or ride-sharing, is a novel and evolving concept. However, existing research often relies on simulations or hypothetical scenarios, with limited empirical investigations. Promoting these services requires understanding residents' willingness to adopt them, but many respondents find it difficult to provide meaningful feedback on innovative mobility options without personal experience (Dorner & Berger, 2018; Hartl & Hofmann, 2022). Trial trips are often necessary for individuals to make informed transport choices. Current studies on community-based electric car sharing primarily focus on rural areas (Dorner & Berger, 2018) or developed urban contexts like Portland (Herman, 2022).

This study adds new insights by examining a developing city with unique challenges such as traffic congestion and limited pedestrian-friendly infrastructure. Specifically, we surveyed participants in a pilot project in Bangkok, Thailand, to better understand the potential for community-based mobility services in this context.

5.1.2 Self-Efficacy to Sustain Behavior Changes in Interventions

To assess the impact of a designed intervention, a recent study examined key factors influencing travel mode shifts in an intervention offering temporary free public transport to reduce car use (Skarin et al., 2019). The intervention approach was divided into two phases of voluntary change, each shaped by distinct psychological determinants. In the pre-intervention phase, personal motivation (e.g., interest and willingness to change) was crucial in encouraging voluntary participation. During the intervention phase, additional psychological factors influenced participants' ability to sustain behavior change. Among these factors, self-efficacy—an individual's belief in their ability to successfully perform specific tasks or behaviors (Bandura, 1977)—emerged as particularly significant. Self-efficacy has been identified as a key determinant of behavior change across various domains (Holly & Watson, 2002).

In the context of travel behavior, transport-related self-efficacy refers to an individual's confidence in managing daily transport challenges. Unlike short-term motivators such as curiosity or interest, self-efficacy has broader and longer-term effects on continuous and voluntary behavior change. The study suggested that self-efficacy plays a more critical role in sustaining behavioral change during interventions than initial motivation. However, the psychological mechanisms underlying the development and maintenance of self-efficacy in this context remain unclear (Skarin et al., 2019).

This study seeks to bridge these gaps by proposing an integrated hypothesized model that explains how specific interventions can drive developmental changes in behavior. The model focuses on the role of self-efficacy in fostering enduring behavior change resulting from interventions. By exploring the relationship between self-efficacy and sustained behavioral intentions—particularly within the context of a community-based electric ride-sharing service—this study aims to uncover the mechanisms that drive ongoing user engagement and long-term commitment. These insights are expected to contribute to more effective and lasting travel behavior interventions.

5.2 Behavior Models and Theories of Changes

Theories of behavior change examine personal, social, and environmental factors to explain how human behaviors are determined. These theories have been widely applied to study the intention to change existing behaviors or adopt new ones across various disciplines. In behavioral science, a distinction is made between behavior models and theories of change (Darnton, 2008). Behavior models focus on identifying the psychological factors that determine specific behaviors, while theories of change are process-oriented, providing insights into how behaviors can evolve over time. Understanding behavior and exploring behavior change are distinct yet complementary research areas.

To reduce private car use by offering an alternative transport option—community-based electric ride-sharing, as studied here—two complementary research lines are needed. The first focuses on identifying the determinant factors that influence users' behavioral intention to adopt the service. The second investigates the cognitive processes users undergo when deciding to continue using the service, substituting it for their current mobility choices. Together, these approaches provide a comprehensive framework for understanding and facilitating behavior change.

5.2.1 Key Constructs Affecting Behavioral Intention

Theory of Planned Behavior (TPB) is a widely recognized behavior model used across various disciplines. With the rapid development of electric vehicles (EVs) and the sharing economy, the TPB has gained increasing attention as a tool to predict user intentions toward emerging mobility services (Zhang et al., 2018; Mattia, Mugion, & Principato, 2019; Eccarius & Lu, 2020). The TPB provides a concise framework for understanding intended behavior, which it posits is determined by three core constructs: attitudes toward the behavior, subjective norms, and perceived behavioral control. Each construct is influenced by antecedent beliefs—specifically, behavioral, normative, and control beliefs (Ajzen, 1985).

While the TPB has been effective in explaining behavioral intentions in numerous studies, researchers have sought to enhance its explanatory power by integrating additional variables to address specific contexts (Sommer, 2011). For example, the TPB has been combined with the Technology Acceptance Model (TAM) (Davis, 1989) to examine how perceived ease of use and perceived usefulness influence users' attitudes toward new transport services and technologies (Chen & Chao, 2011; Haldar & Goel, 2019). The theorical framework of TPB and TAM is presented in **Figure 5.1**.

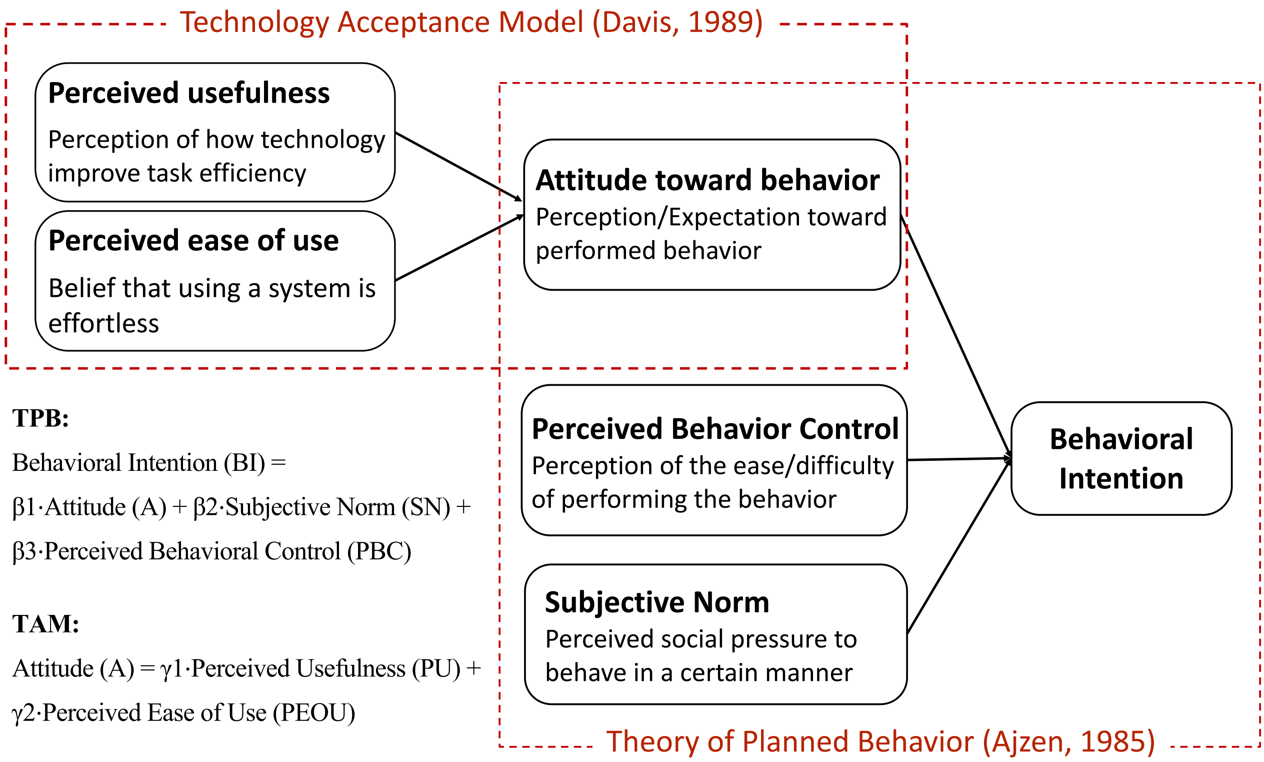

Figure 5.1 Theorical framework of TPB and TAM.

In this study, we adopt an integrated TPB and TAM model as the foundational framework to explore the determinants of user intention to adopt community-based mobility as an innovative transport service. Additionally, based on previous research, we incorporate trust as an additional psychological factor in the hypothesized model. Trust is defined as "the attitude that an agent will help achieve an individual's goals in a situation characterized by uncertainty and vulnerability" (Lee & See, 2004, p. 51). It has been identified as a critical construct influencing individual intentions to adopt new transport technologies, including autonomous vehicles (Abraham et al., 2017; Chen, 2019) and mobility-management tools (Dastjerdi et al., 2019).

In the following subsections, we review the cited core constructs and evaluate their applicability and sufficiency in determining residents' intentions to use community-based mobility services.

Attitudinal Variables

In both the TPB and TAM models, attitudes toward behavior refer to an individual's favorable or unfavorable evaluation of a specific behavior (Moon & Kim, 2001). According to Ajzen (1985), attitudes are shaped by considering the potential outcomes of performing the behavior. In the context of transport, this study posits that attitudes toward a specific mode of transport should account for travelers' expectations of service performance.

Recent studies have increasingly introduced the concept of consumer value creation to describe various dimensions of attitudes toward using EVs (Schuitema et al., 2013). Two prominent values often discussed are instrumental and hedonic values:

- ***Instrumental Value*** refers to the functionality or utility provided by a service to achieve a user's desired goals (Smith & Colgate, 2007). In this context, instrumental attitudes reflect travelers' expectations regarding the practical outcomes of using a transport service, such as effectiveness, reliability, and safety.
- ***Hedonic Value*** relates to the ability of a service to create positive experiential feelings and emotions for users (Smith & Colgate, 2007). Hedonic attitudes capture travelers' expectations of the emotional satisfaction derived from using the service, including enjoyment and pleasure.

Both instrumental and hedonic attitudes have been emphasized in numerous empirical studies. Research suggests that these two dimensions play distinct roles in shaping the adoption of emerging mobility services, such as electric mopeds, scooters, and small cars (Curtale & Liao, 2020; Kopplin et al., 2021; Putri et al., 2021). By considering these attitudinal dimensions, this study aims to better understand the factors influencing user acceptance of community-based services.

Normative Beliefs and Norms

Subjective norm refers to an individual's perception of social pressure to perform or avoid certain behaviors, particularly influenced by significant others such as family and friends. Within the context of the TPB, the relationship between subjective norm and behavioral intention is often weaker compared to attitudes and perceived behavioral control. Armitage and Conner (2001) attribute this weaker correlation to the limited scope of subjective norms, prompting calls for improved measures and expanded research (Krueger et al., 2000; Rivis & Sheeran, 2004).

In contrast, social norm represents the shared beliefs, values, and expectations within a society or social group. Social norms guide behavior by reflecting what is considered acceptable or appropriate in a particular context. According to UNICEF (2021), social norms exist when individuals practice a behavior either because they believe others in their community engage in it (descriptive norms) or because they feel those who matter to them approve of it (injunctive norms). A prominent example of a shared social norm is environmental consciousness or "being green," which has been identified as a collective value that supports lasting positive behavior changes in interventions (Welsch & Kühling, 2017; UNICEF, 2021).

While subjective norms focus on perceived social pressure from significant others, social norms encompass broader societal beliefs and behavioral standards. Both types of norms have proven significant in different contexts: subjective norms are key predictors of green purchase intentions (e.g., buying an EV) (McCoy & Lyons, 2014; Dutta & Hwang, 2021; Zhuang, Luo, & Riaz, 2021), whereas social norms are more influential in encouraging environmental behaviors (Steg & Vlek, 2009; Binder, Blankenberg, & Welsch, 2019).

Choosing a shared electric transport service instead of private cars or petroleum-fueled taxis aligns with eco-friendly behavior and represents a socially desirable decision. This study incorporates social norms as a determinant, given their established link to environmental behaviors. Social norms exert normative influence over individual actions, offering valuable insights into how environmental behaviors align with the expectations of one's social group. Recognizing this connection allows policymakers and service providers to design interventions and policies that leverage social norms to encourage and sustain pro-environmental behaviors effectively.

Self-Efficacy in Transport

As an extension of the TRA (Ajzen & Fishbein, 1980), the TPB was developed by incorporating the concept of perceived behavioral control, which originated from self-efficacy theory. Self-efficacy, a core element in many behavior change theories, including social cognitive theory (Bandura, 1991, 1999, 2001), the health belief model (Rosenstock, 1974), and the health action process approach (Schwarzer, 1992), refers to an individual's belief in their ability to control their functioning and navigate daily events (Bandura, 1977). It represents confidence in one's capability to succeed in specific situations. In contrast, perceived behavioral control (Ajzen, 1985) captures an individual's perception of control over engaging in a behavior, considering potential obstacles or constraints.

The original TRA primarily emphasized the direct influence of intentions on behavior. However, it became evident that intentions alone are insufficient, as external or internal limitations can hinder behavior execution. TPB addresses this gap by including perceived behavioral control as a determinant, recognizing that individuals may intend to act but still encounter barriers that prevent them from following through.

While self-efficacy and perceived behavioral control are related, they are distinct constructs. Self-efficacy emphasizes personal competence and effectiveness, focusing on an individual's confidence in achieving specific goals. Perceived behavioral control, on the other hand, considers the ease or difficulty of performing a behavior, accounting for both internal capabilities and external constraints. This study focuses on the broader and longer-term effects of self-efficacy on individuals' adaptive attitudes and behaviors. According to Bandura (1982), self-efficacy plays a pivotal role in motivation, goal-setting, and perseverance in the face of challenges, making it crucial for understanding and promoting sustained behavior change.

Self-efficacy can be categorized as task-specific or general. Task-specific self-efficacy assesses an individual's confidence in performing a particular task, while general self-efficacy has a broader impact across various daily situations. General self-efficacy influences how individuals interpret information, shape behaviors, and perform tasks (Bandura, 1994; Wilde & Hsu, 2019).

Transport and mobility are foundational to supporting a wide range of daily activities. It is essential to enhance residents' general self-efficacy in daily transport by developing efficient systems with sufficient mobility options before encouraging a shift away from private car use. Although substantial research has explored self-efficacy in the context of public transport adoption or new transport technologies, most studies focus on task-specific self-efficacy (e.g., Castel et al., 2019; Lee et al., 2019; Zhu, Zheng, & Chen, 2022), assessing confidence in using a particular service. However, a more comprehensive evaluation of general self-efficacy in daily transport, referred to as travel-related self-efficacy in this study, is needed.

This study examines whether the promoted community-based transport service can effectively satisfy residents' travel needs and serve as a viable option to reduce dependence on private vehicles. By assessing travel-related self-efficacy, the research aims to provide a holistic understanding of how such services can impact mobility choices and contribute to sustainable transport behavior.

5.2.2 Cognitive Process to Decide a Sustained Behavior Change

Goal-framing theory (Lindenberg & Steg, 2007), rooted in cognitive social psychology, highlights the critical role of goals in shaping cognitive processes that sustain behaviors. The theory identifies three primary goals driving human motivation: hedonic goals (enhancing personal well-being), normative goals (aligning with societal or moral standards), and gain goals (optimizing resources and minimizing effort). Pro-environmental behaviors, defined as deliberate actions to reduce environmental impact or improve environmental quality (Jensen, 2002; Steg & Vlek, 2009), are often influenced by these goals. While goal-framing theory has been applied in various contexts (Hameed & Khan, 2020; Onwezen, 2023), its use in travel behavior is relatively limited.

A Swedish study (Westin et al., 2020) explored how framing transport-related measures, such as increasing parking fees to discourage car use, with hedonic, normative, and gain goals affected public acceptance. The results showed that goal-framed messages significantly improved perceptions of fairness, justice, and effectiveness compared to no communication, supporting the hypothesis that goal framing is crucial for fostering behavior change during and after interventions. By aligning goals with personal values and perceived benefits, goal framing enhances motivation and the likelihood of maintaining desired behaviors over time. This framework offers valuable insights for designing interventions to encourage lasting behavioral change.

Though the goal framing theory is scarcely applied in explaining travel behavior, a recent Sweden study (Westin et al., 2020) examined how the three goal frames—hedonic, normative, and gain—influenced public acceptance of a transport-related measure aimed at reducing private car use by increasing parking fees. The study communicated the rationale for the measure using messages framed around each goal and assessed their impact on perceptions of fairness, justice, and effectiveness. The results showed that goal-framed messages were significantly more effective in generating policy acceptance compared to no communication (control group), highlighting the importance of aligning messaging with individuals' goals. These findings empirically support the theoretical hypothesis that identifying and framing goals is crucial for encouraging behavior change during and after an intervention.

Goal-framing theory asserts that how individuals frame or perceive goals profoundly affects their motivation, perceived benefits, and alignment with personal values, ultimately shaping their intention to sustain the behavior over time.

5.3 Hypothesized Model

The integration of the TPB and goal-framing theory offers a comprehensive framework for understanding sustained behavioral intention. While TPB serves as the foundation for identifying the initial determinants of behavioral intention, goal-framing theory deepens the understanding of the mechanisms that sustain this intention over time. To enhance the TPB's explanatory power in this study, an additional factor—trust in the new transport service—was introduced. This adaptation aligns with the study context and aims to improve the model's relevance and predictive accuracy.

Within this integrated framework, travel-related self-efficacy plays a pivotal role as a mediator. It facilitates the identification of goals and provides meaning to the sustained travel behavior changes initiated by interventions. As a cornerstone of human motivation, self-efficacy influences key processes such as goal setting, action execution, persistence, and self-accomplishment (Bandura, 1997, 1986; Schunk & DiBenedetto, 2021). Based on prior research (Bandura, 1982), this study posits that external influences, such as measures implemented in an intervention, primarily affect human functioning indirectly through the mediating role of self-efficacy.

The proposed relationships between the extended factors and the existing TPB framework are established through a review of antecedent-consequence relationships in the literature. The integrated model, illustrating these connections, is presented in **Figure 5.2**.

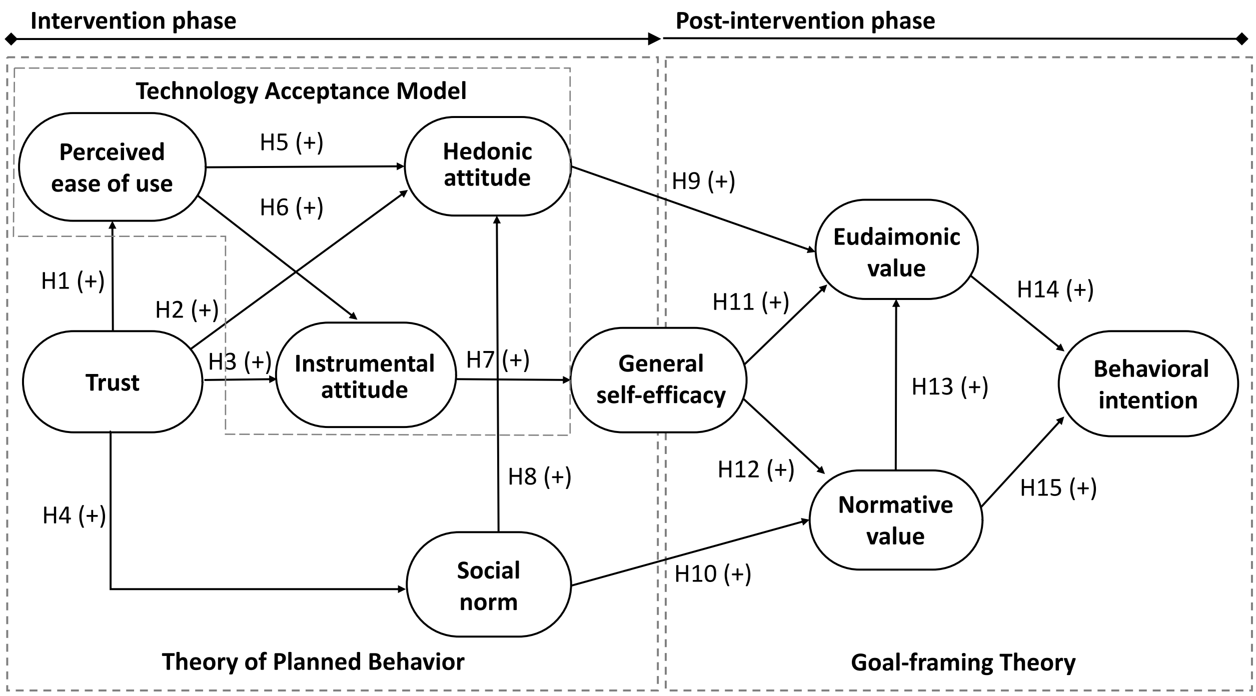

Figure 5.2 The proposed model.

This study positions trust as a critical antecedent influencing individuals' intention to adopt new mobility services. Trust is hypothesized to positively affect perceived ease of use (H1) by reducing uncertainty and enhancing the perceived reliability of the service (Lee & See, 2004). Previous studies (e.g., Chen, 2019; Shao et al., 2020) suggest that trust can influence behavioral intention indirectly by shaping attitudinal variables (H2, H3). Additionally, trust is proposed to influence normative expectations by fostering shared beliefs within a social group, thereby aligning individual behaviors with perceived social norms (H4). This link between trust and normative beliefs is supported by Wu and Chen (2005), emphasizing trust as an antecedent of normative belief.

The model adapts attitudes toward behavior into two distinct components: instrumental attitudes (utility-based) and hedonic attitudes (pleasure-based). Similarly, subjective norm is adapted as social norm, as outlined in earlier sections. Drawing from the TAM, perceived ease of use is hypothesized to influence both instrumental and hedonic attitudes (H5, H6). Guided by the goal-framing theory, instrumental attitudes (reflecting gain goals) are expected to positively influence travel-related self-efficacy (H7). Additionally, social norms are hypothesized to enhance the hedonic value of using community-based ride-sharing services (H8), as conformity to perceived norms may amplify enjoyment in eco-friendly transportation practices (Flores & Jansson, 2022).

This study introduces eudaimonic value as a replacement for hedonic goals in the goal-framing theory. Eudaimonic value refers to individuals' pursuit of quality of life through self-realization and the achievement of personally meaningful goals (Waterman et al., 2010). While interconnected, hedonic and eudaimonic values are distinct constructs, with definitions well-established in the literature (Kashdan et al., 2008). In the hypothesized model, hedonic attitudes (short-term well-being) are proposed to positively influence eudaimonic value (long-term well-being) (H9). Furthermore, normative value, representing personal moral obligations towards environmental responsibility, is hypothesized to be positively influenced by social norms (H10).

Building on Bandura's (1982) work, this study hypothesizes that travel-related self-efficacy, acting as a mediator, will positively influence behavioral intention by enhancing both eudaimonic value (H11) and normative value (H12). In alignment with the goal-framing theory, normative value is expected to positively affect eudaimonic value (H13). Finally, both eudaimonic and normative values are hypothesized to directly influence the intention to sustain behavior changes (H14, H15). These relationships form the foundation of the integrated framework, offering insights into the psychological and social mechanisms driving sustained engagement with community-based and eco-friendly mobility services.

5.4 Materials and Methods

5.4.1 Study Site and Contexts

The urban structure of Bangkok is characterized by large superblocks surrounded by arterial roads, with a notable lack of internal cross-street networks. Instead, the city features numerous narrow side streets, known as "sois" in Thai, which branch off major streets and extend into central blocks (Pujinda & Yupho, 2017). Historically used as waterways, many sois now function as dead-end roads, creating challenges for two-way traffic. Despite these limitations, sois serve as critical local residential streets, connecting residents to essential services and facilities for daily activities.

This unique urban layout hinders convenient access to public transit and contributes to severe traffic congestion and air pollution in neighborhoods. Given these challenges, community-based development offers a promising approach for addressing Bangkok's urban mobility needs. The dense and compact street spaces typical of Bangkok's urbanization (Pujinda & Yupho, 2017) require alternative connectivity solutions that prioritize friendly and sustainable modes of transport. Community-based initiatives could provide such alternatives, enhancing accessibility while alleviating congestion and environmental impacts.

Pilot Project and Data Collection

The Smart Small Vehicle Service (SSVS), a community-based electric ride-sharing initiative, was piloted in the Vadhana district, central Bangkok, from December 2021 to March 2023. This project aimed to assess the feasibility of implementing community-based electric mobility services and evaluate their integration with public transport systems. Initially, the target users were international condominium residents, chosen for feasibility analysis before expanding to local Thai residents. These foreign residents, particularly Japanese nationals, showed a high reliance on ride-hailing services or costly private hire options (e.g., limousine services) for neighborhood travel. The pilot project sought to determine whether SSVS could adequately meet travel demands in a scenario where users do not own a private car or cannot drive.

The service area covered three collaborative condominiums, accommodating approximately 280 Japanese residents (see **Figure 5.3** for a map). The area spans the central portion of the Vadhana district, extending eastward from Asok/Sukhumvit transit, westward from Thong Lor station, southward to Sukhumvit Road, and northward to the Saen Saeb Canal. SSVS operated along narrow sois (side streets), connecting the condominiums to key neighborhood facilities such as hospitals and local shops, as well as nearby public transit stations.

The condominiums were located relatively close to transit stations, with distances of 1.8 km, 1.3 km, and 1.1 km from BTS Phrom Phong station. While the commonly cited acceptable walking distance (AWD) to transit is 400 m for bus stops and 800 m for rapid transit stations (El-Geneidy et al., 2014; Pueboobpaphan et al., 2022), these standards may not apply to Thailand's tropical climate. In Bangkok, the AWD to rapid transit stations is significantly shorter, approximately 320 m (Townsend & Zacharias, 2010). Given this context, the proximity of the condominiums to mass transit stations made them ideal for evaluating SSVS as a last-mile ride-sharing solution, addressing gaps in public transit accessibility and improving neighborhood connectivity.

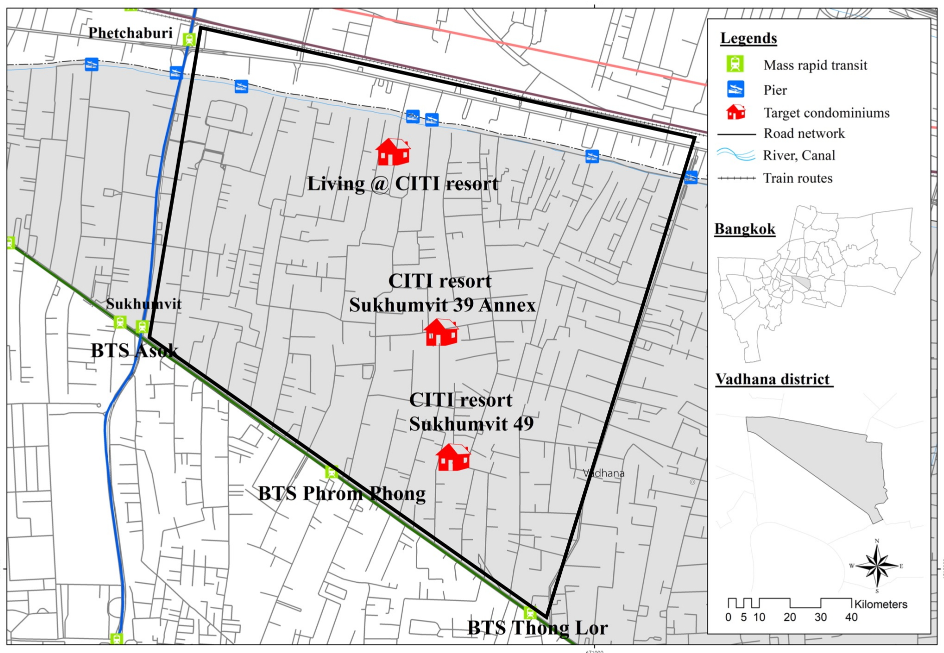

Figure 5.3 The area outlined with solid black lines represents the designated service area.

The vehicle used in the pilot project is the FOMM ONE, a compact four-seat electric vehicle (EV) measuring 2.6 meters in length and 1.3 meters in width. The FOMM ONE occupies approximately 60% of the road space required by a standard vehicle. The service operates daily from 8:00 to 12:00 and 13:00 to 17:00, utilizing a fleet of three EVs driven by hired Thai drivers.

Reservations for the service are managed through the LINE application, where users can book rides in advance or opt for immediate use. The user-friendly interface allows residents to specify pick-up and drop-off locations within the service area. As a pilot initiative, the service is free of charge.

To evaluate user experiences and sustained interest, an online survey was conducted among registered SSVS users from November 21 to November 30, 2022, after approximately one year of operation. This timing allowed for the collection of insights on users' intentions following an extended trial period, shedding light on their long-term commitment to the service. The survey was hosted on an online platform, and the link was distributed to all registered pilot service users via the LINE application.

Characteristics of Participants and Travel Patterns

A total of 250 individuals registered and used the pilot service at least once during its operation. From this group, 101 valid survey responses were collected, resulting in a response rate of 40.4%. **Table 5.1** presents the characteristics of the respondents.

Table 5.1 Sample profile.

Characteristics	Sample size (n=101)	Percentage (%)
Gender		
Male	28	27.7
Female	60	59.4
Prefer not to answer	13	12.9
Marriage		
Married	88	87.1
Single	1	1.0
Prefer not to answer	12	11.9
Number of members in family		
Live alone	12	11.9
2 persons	15	14.9
3-4 persons	59	58.4
More than 5 persons	4	4.0
Prefer not to answer	11	10.9
Available private transport (multiple-choice question)		
Car driven by myself	2	2.0

Car with a driver (e.g., private hire vehicle)	66	65.3
Motorcycle	6	5.9
Private mobility is not available	35	34.7
Primary modes for first and last-mile transport (select up to three answers)		
Walk	68	67.3
Private cars	14	13.9
Smart Small Vehicle Service (SSVS)	61	60.4
Shuttle services provided by the condominium	69	68.3
Ride-hailing cars (e.g., taxi, Grab car)	19	18.8
Motorcycle taxi	10	9.9
Three-wheeled taxi (i.e., Tuk-Tuks)	21	20.8

Approximately 60% of respondents were female, and over 87% were married. The survey targeted local residents with limited transport options, revealing that 34.7% of respondents did not own private transportation, while 65.3% relied on household-owned private vehicles operated by hired drivers. This highlights a household dynamic where the primary household member, often the head, tends to monopolize car use for commuting or social activities, leaving other family members without access to the vehicle during the day.

Additionally, the majority of respondents (62.4%) belonged to households with three or more family members. This finding underscores that even in households with access to private vehicles, individual mobility options are constrained, as family members must navigate shared access to limited transport resources. These insights shed light on the challenges faced by households in managing mobility needs and the potential role of community-based services in addressing these gaps.

Transport Mode Preferences

To investigate transport mode preferences, respondents were asked: “What is the mode you frequently choose for traveling a short distance from home, such as to a nearby supermarket or public transport station?” Respondents could select up to three answers. The results showed that walking (67.3%) and the shuttle service offered by the condominium (68.3%) were the most frequently used modes, followed by the SSVS (60.4%). Other modes included three-wheeled taxis (20.8%), ride-hailing cars (18.8%), and motorcycle taxis (9.9%), which remained primary options for some users during the pilot project.

The condominium’s shuttle service, typically a 10-passenger van, was often underutilized except during peak hours in the morning and evening, according to interviews with the condominium manager. However, its fixed-route and fixed-time scheduling posed challenges in meeting residents’ flexible travel needs, highlighting the potential benefits of the more adaptive SSVS.

Service Usage and Trends

The pilot service saw increased usage over time, despite challenges in service quality. In the last week of May 2022, the SSVS completed 40.1 trips and served 57.1 passengers daily. By the last week of November 2022, these numbers had increased to 52.1 trips and 80.9 passengers daily, representing a 30% increase in trips and a 41.7% increase in passengers. However, during this period, the average waiting time rose from 5.4 minutes in May to 7.0 minutes in November, and the service offer rate—the percentage of reservations successfully served—declined from 90% to 79%. Despite these declines in service levels, users continued to rely on the service, indicating its value in meeting users' needs.

The majority of trips (97.9%) involved home-based Origin-Destination (OD) pairs, confirming the service's role as a connector between residential areas and key destinations. The most traveled OD was from the condominium (home) to the BTS Phrom Phong station, covering a distance of approximately 2.5 km and accounting for 19.8% of all trips. Other popular destinations included transit stations (43.8%), supermarkets (19.5%), hospitals (7.1%), and educational facilities (6.9%).

Travel patterns revealed peak usage in the morning (8:00–10:00) for trips to transit stations and in the evening (16:00–17:00) for return trips from transit stations. These patterns highlight the SSVS's role as an effective first- and last-mile mobility solution, enhancing connectivity between residential areas and public transit while reducing reliance on private vehicles.

5.4.2 Measures

This study adapted and modified measurement scales from existing literature to suit the research context. All constructs were assessed using a five-point Likert scale, where respondents indicated their agreement or disagreement with statements (1 = "strongly disagree" to 5 = "strongly agree").

Perceived ease of use and trust were measured with two items adapted from Chen (2019), supplemented with an additional item developed specifically for this study to reflect the study context. Instrumental and hedonic attitudes were assessed using three items adapted from Zhu et al. (2022). The social norm construct was evaluated through three items adapted from Dutta and Hwang (2021). Travel-related self-efficacy was measured with four items proposed by Chou et al. (2022) and further refined for this study. Normative value was captured using three items, two adapted from Kim and Choi (2005) and one created for this study.

To measure eudaimonic value, three items were designed based on Waterman et al. (2010). These items explored (1) users' sense of purpose and meaning in using the service, (2) their enjoyment of the activity as personally expressive, and (3) their self-discovery through engaging with an innovative service, leading to greater openness to new challenges. Behavioral intention was assessed with four items specifically tailored by the authors to align with the study's objectives and context.

Demographic questions included information about respondents' gender, marital status, and family status. Additional travel-related questions addressed the availability of private transport and respondents' transport mode preferences, providing a comprehensive understanding of their travel behaviors and contexts.

5.4.3 Data analysis

This study utilized structural equation modeling (SEM) with maximum likelihood estimation to analyze interrelated dependence relationships among latent variables and constructs. The data analysis followed a two-stage approach. In the first stage, scale validation was conducted using confirmatory factor analysis (CFA) to ensure construct validity by testing convergent reliability and discriminant validity of the measurement model. In the second stage, the hypothesized structural model was empirically tested.

The SEM fit indices used in this study included the normed chi-square (χ^2/df), comparative fit index (CFI), Tucker-Lewis index (TLI), goodness-of-fit index (GFI), and root mean square error of approximation (RMSEA). A normed chi-square value of less than 2.0 is considered good, while values below 5.0 are acceptable (Marsh & Hocevar, 1985). For other indices, values above 0.9 indicate a good model fit (Hair, 2009). An RMSEA value of up to 0.08 is regarded as reasonable (MacCallum, Browne, & Sugawara, 1996).

To explore differences in results based on respondents' transport mode preferences, a multi-group SEM analysis was conducted to compare parameter estimates across groups. Recognizing the limitations of sample division in multi-group analysis, this study also applied moderating effect analysis using PLS-SEM as a complementary method. Moderating effect analysis assesses relationships across different levels of a third construct, enhancing precision without dividing the sample. Together, these approaches provided a robust examination of parameter differences and moderating effects, even when working with a small sample size. Detailed results are included in the Appendices.

5.5 Results

5.5.1 Descriptive Statistics

Table 5.2 shows the descriptive statistics, including item means and standard deviation of each construct in the hypothesized model.

Table 5.2 Descriptive statistics of survey items.

Constructs and items		Mean	S.D.
Perceived ease of use (PE)			
PE1	The way to use SSVS is clear and understandable.	4.18	0.91
PE2	The LINE reservation interface is easy to use for me.	4.42	0.97

PE3	The reservation function of SSVS is useful.	3.76	1.12
Trust (TR)			
TR1	I believe that SSVS provides a robust and safe environment in which I can use the service.	3.86	0.93
TR2	I trust that the SSVS provider has enough safeguards to protect me from liability or damage.	3.81	0.91
TR3	I think SSVS is punctual and reliable	3.08	1.12
Social norm (SN)			
SN1	Mass media shared information regarding the benefits of electric vehicles, influencing me that I should use SSVS.	1.95	1.20
SN2	The promotion that conveyed SSVS is eco-friendly mobility attracted me to use it.	2.76	1.58
SN3	Seeing the electric SSVS cars running on the streets would attract me to use it.	2.99	1.59
Instrumental attitude (IA)			
IA1	SSVS enables me to reach my destinations more quickly.	4.46	0.66
IA2	SSVS helps me save my effort on travel.	4.60	0.60
IA3	SSVS improves my safety compared to other travel modes.	4.26	0.82
Hedonic attitude (HA)			
HA1	Traveling using SSVS would be pleasant overall.	3.82	0.85
HA2	I am satisfied with the ride comfort of SSVS.	3.79	0.96
HA3	I enjoy my journey with SSVS.	4.00	0.79
Travel-related self-efficacy (TS)			
TS1	I feel less worried when going out because SSVS serves me as a reliable option.	4.45	0.81
TS2	SSVS makes me feel secure by ensuring my daily mobility.	4.50	0.77
TS3	I feel freer in daily transport and movement with SSVS.	4.42	0.75
TS4	I become able to move around on my own without relying on others if SSVS is available.	4.43	0.82
Eudaimonic value (EV)			
EV1	I think it is meaningful to prioritize the use of SSVS even if I have other alternative mobility.	4.33	0.69
EV2	I enjoy using SSVS no matter how other people are impressed by it.	4.42	0.71
EV3	I have been more willing to try new services or technologies.	4.59	0.60
Normative value (NV)			
NV1	I believe that everyone has a responsibility to use eco-friendly transport.	4.17	0.83
NV2	I believe using eco-friendly transport would benefit the environment in the long term.	4.23	0.79
NV3	I believe that shared mobility service would be a solution to solve traffic congestion.	4.19	0.87

Behavioral intention (BI)			
BI1	I prefer SSVS rather than hailing a taxi, Tuk-Tuk, or Grab car.	4.67	0.67
BI2	I intend to use SSVS to substitute private car or motorcycle trips.	4.40	0.93
BI3	If the free service becomes available permanently, I intend to use it.	4.91	0.43
BI4	If the SSVS starts to charge users, I will still consider using it.	3.66	1.06

5.5.2 Measurement Model

A preliminary CFA was conducted to assess the measurement model. Seven items were removed to improve reliability and reduce measurement error because their standardized factor loadings did not meet the minimum criterion of 0.5 (Hair, 2009). The eliminated items included one each from perceived ease of use (PE3), trust (TR3), social norm (SN3), travel-related self-efficacy (TS4), and normative value (NV3), as well as two items from behavioral intention (BI3, BI4). After excluding these items, the CFA was performed again.

The revised model demonstrated good fit indices: $\chi^2(173) = 274.358$, $\chi^2/df = 1.59$, CFI = 0.93, TLI = 0.90, and RMSEA = 0.076, despite a lower GFI value of 0.83. According to Baumgartner and Homburg (1996), model complexity (e.g., number of observed variables and estimated parameters) can negatively impact GFI and AGFI values. However, fit indices such as χ^2/df, RMSEA, and TLI are considered more robust for accounting for model complexity. Research suggests that a GFI range of 0.80 to 0.89 may still indicate a reasonable fit (Doll, Xia, & Torkzadeh, 1994; Hoyle, 1995).

As shown in **Table 5.3**, the standardized factor loadings ranged from 0.576 to 0.969, exceeding the required threshold of 0.50. Both Cronbach's α and composite reliability (CR) estimates for all constructs met the recommended level of 0.70. Additionally, all average variance extracted (AVE) values were above the suggested minimum of 0.50, confirming convergent validity.

Discriminant validity was verified using Fornell and Larcker's (1981) criterion. **Table 5.4** indicates that the square root of each construct's AVE exceeded its inter-construct correlations with all other measured constructs in the structural model. These results support the robustness of the measurement model and its validity for further structural analysis.

Table 5.3 CFA results of the measurement model.

Construct	Item	Standard factor loading	Standard error	Cronbach's α	CR	AVE
Perceived ease of use	PE1	0.873	0.085	0.779	0.781	0.641
	PE2	0.732	0.093			
Trust	TR1	0.858	0.081	0.848	0.848	0.736
	TR2	0.857	0.080			
Social norm	SN1	0.661	0.128	0.743	0.815	0.706
	SN2	0.928	0.180			
Instrumental attitude	IA1	0.711	0.058	0.817	0.833	0.630
	IA2	0.860	0.049			
	IA3	0.807	0.069			
Hedonic attitude	HA1	0.747	0.079	0.732	0.757	0.520
	HA2	0.784	0.087			
	HA3	0.576	0.078			
Travel-related self-efficacy	TS1	0.885	0.063	0.948	0.949	0.861
	TS2	0.969	0.056			
	TS3	0.933	0.056			
Eudaimonic value	EV1	0.827	0.059	0.807	0.827	0.623
	EV2	0.857	0.059			
	EV3	0.622	0.056			
Normative value	NV1	0.693	0.077	0.798	0.813	0.690
	NV2	0.959	0.069			
Behavioral intention	BI1	0.823	0.062	0.737	0.748	0.600
	BI2	0.749	0.088			

Table 5.4 Results of discriminant validity.

Construct	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Perceived ease of use	**0.80**								
(2) Trust	0.12	**0.86**							
(3) Social norm	0.01	0.19	**0.84**						
(4) Instrumental attitude	0.41	0.24	0.04	**0.79**					
(5) Hedonic attitude	0.31	0.47	0.23	0.35	**0.72**				
(6)Travel-related self-efficacy	0.21	0.11	0.00	0.76	0.15	**0.93**			
(7) Eudaimonic value	0.26	0.38	0.06	0.46	0.27	0.28	**0.79**		
(8) Normative value	0.31	0.13	0.13	0.17	0.36	0.04	0.36	**0.83**	
(9) Behavioral intention	0.15	0.25	0.07	0.17	0.23	0.09	0.57	0.34	**0.78**

Note: Values on the diagonal of correlation matrices represent the square root of the AVEs.

In the final factor structure, nine constructs were included, five of which comprised two items each. Notably, the measurement model assessment revealed no Heywood cases, indicating the absence of negative variance and confirming the model's robustness. To supplement the evaluation conducted using CB-SEM, PLS-SEM results are provided in **Appendix 5A** (Hair et al., 2012), further supporting the construct and discriminant validity across both methods. This dual-method approach enhances confidence in the reliability and validity of the measurement model.

5.5.3 Structural Model and Hypotheses Test

The hypothesized structural model was estimated to examine the relationships between constructs. The model demonstrated an acceptable fit based on the goodness-of-fit indices: $\chi^2(173) = 280.55$, $\chi^2/df = 1.62$, CFI = 0.92, TLI = 0.90, GFI = 0.81, and RMSEA = 0.078. These values indicate that the structural model aligns well with the sample data.

Figure 5.4 presents the estimated model, showing the standardized path coefficients and significance levels. Of the 15 hypothesized relationships, 13 were empirically supported. The exceptions were H12, which hypothesized a positive effect of travel-related self-efficacy on normative value ($\beta = 0.192$, $p = 0.059$), and H15, which hypothesized a positive effect of normative value on behavioral intention ($\beta = 0.206$, $p = 0.070$). Although these two paths were not statistically significant, both demonstrated trends toward significance, suggesting potential relationships that may warrant further investigation. These results confirm the validity of most of the hypothesized relationships, providing valuable insights into the interplay between constructs in the model.

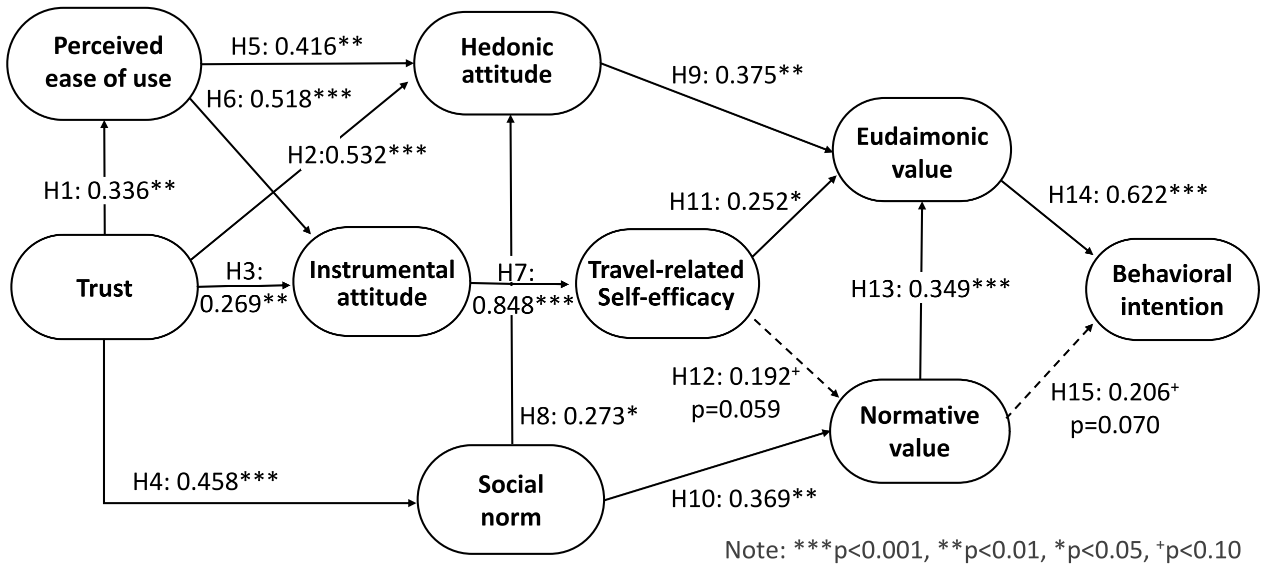

Figure 5.4 The estimated model.

Trust demonstrated significant positive effects across multiple constructs. It positively influenced users' perceived ease of use (H1: $\beta = 0.336$, $p < 0.01$), hedonic attitudes (H2: $\beta = 0.532$, $p < 0.001$), instrumental attitudes (H3: $\beta = 0.269$, $p < 0.01$), and social norm (H4: $\beta = 0.458$, $p < 0.001$). Perceived ease of use also had significant positive effects on both hedonic attitude (H5: $\beta = 0.416$, $p < 0.01$) and instrumental attitudes (H6: $\beta = 0.518$, $p < 0.001$). Among these, instrumental attitude strongly influenced travel-related self-efficacy (H7: $\beta = 0.848$, $p < 0.001$).

Social norm positively impacted hedonic attitude (H8: $\beta = 0.273$, $p < 0.05$) and normative value (H10: $\beta = 0.369$, $p < 0.01$), with normative value further enhancing eudaimonic value (H13: $\beta = 0.349$, $p < 0.001$) and showing a trend toward positively influencing behavioral intention. Both hedonic attitude (H9: $\beta = 0.375$, $p < 0.01$) and travel-related self-efficacy (H11: $\beta = 0.252$, $p < 0.05$) significantly contributed to eudaimonic value in using the community-based sharing service.

These results underscore the critical role of eudaimonic value as a mediating variable, directly contributing to behavioral intention. A strong, significant correlation was observed between eudaimonic value and behavioral intention (H14: $\beta = 0.622$, $p < 0.001$), emphasizing its importance in fostering sustained user engagement.

5.5.4 Multi-Group Analysis

The SSVS was offered as a free transport option to the target residents. Among the 101 respondents, 61 identified as frequent users of SSVS for trips to nearby public transit or facilities, while 40 were infrequent users, favoring private cars, ride-hailing, or taxis for first- and last-mile transport. This study used SSVS usage frequency as a moderator and conducted a multi-group analysis to explore its moderating effects on the hypothesized structural model.

The unconstrained models were compared with the structural weight model, in which regression coefficients between latent variables were set to be equal across subgroups. Significant moderating effects would manifest as statistically significant differences in the empirical relationships between these models within the subgroups (Bamberg, 2003; Li & Zhang, 2021). A chi-square difference test between the unconstrained model ($\chi^2 = 551.96$, $df = 346$) and the structural weight model ($\chi^2 = 625.97$, $df = 373$) revealed a significant difference ($\Delta\chi^2(27) = 74.009$, $p < 0.001$), confirming notable subgroup differences.

Further chi-square tests were conducted on individual regression coefficients by constraining each path one at a time. The results revealed significant differences in four paths, with notable moderating effects identified for two key relationships: H3 (trust → instrumental attitudes, $p < 0.05$) and H13 (normative value → eudaimonic value, $p < 0.01$). In contrast, the paths H8 (social norm → hedonic attitude) and H10 (social norm → normative value) were insignificant in both subgroups, indicating no moderating effect for these relationships.

Table 5.5 summarizes the findings of multi-group analysis. Moderating effect analysis, which is a similar approach, is available in **Appendix 5B**. **Appendix 5C** provides t-test results comparing frequent and infrequent SSVS users. The results confirm that mode preference for SSVS significantly moderates the relationships described in H3 and H13, aligning with the multi-group analysis findings.

Table 5.5 Multi-group analysis results for the moderating effects of SSVS frequent use.

Path	Fully constrained		Unconstrained				Test results for each constrained path	
			Frequent user		Infrequent user			
	Estimate	P	Estimate	P	Estimate	P	Chi-square	P
H1: TR→PE	0.365	**	0.295	*	0.499	*	$\Delta X^2(1) = 0.58$	ns
H2: TR→HA	0.483	***	0.446	***	0.546	**	$\Delta X^2(1) = 0.17$	ns
H3: TR→IA	0.202	***	0.115	ns	0.400	**	$\Delta X^2(1) = 4.88$	*
H4: TR→SN	0.452	***	0.556	**	0.091	ns	$\Delta X^2(1) = 3.30$	ns
H5: PE→HA	0.267	**	0.272	*	0.116	ns	$\Delta X^2(1) = 0.83$	ns
H6: PE→IA	0.265	***	0.242	**	0.185	*	$\Delta X^2(1) = 0.18$	ns
H7: IA→TS	1.266	***	1.050	***	1.731	***	$\Delta X^2(1) = 2.59$	ns
H8: SN→HA	0.197	*	0.164	ns	1.587	ns	$\Delta X^2(1) = 8.91$	**
H9: HA→EV	0.417	***	0.519	**	0.442	*	$\Delta X^2(1) = 0.05$	ns
H10: SN→NV	0.237	**	0.150	ns	2.034	ns	$\Delta X^2(1) = 9.70$	**
H11: TS→EV	0.153	*	-0.030	ns	0.351	**	$\Delta X^2(1) = 1.63$	ns
H12: TS→NV	0.141	ns	0.156	ns	0.119	ns	$\Delta X^2(1) = 0.03$	ns
H13: NV→EV	0.349	***	0.544	***	-0.103	ns	$\Delta X^2(1) = 8.27$	**
H14: EV→BI	0.771	***	1.077	***	0.597	*	$\Delta X^2(1) = 1.44$	ns
H15: NV→BI	0.233	ns	0.003	ns	0.298	ns	$\Delta X^2(1) = 1.23$	ns

Note: ns: non-significant; *** p < 0.001, ** p < 0.01, * p < 0.05.

5.5.5 Affordable Mobility to Secure Transport Self-Efficacy

Respondents demonstrated high levels of travel-related self-efficacy when using SSVS as a daily transport option, with an overall mean score of 4.45 on a five-point Likert scale (1 = strongly disagree, 5 = strongly agree). The four items designed to assess self-efficacy highlighted the service's ability to meet residents' needs, including providing carefree mobility (TS1, mean = 4.45), making users feel secure (TS2, mean = 4.50), enabling greater freedom (TS3, mean = 4.42), and fostering a sense of independence (TS4, mean = 4.43). T-tests revealed that frequent SSVS users reported significantly higher scores on all self-efficacy items compared to infrequent users ($p < 0.01$), as illustrated in **Figure 5.5**.

To further investigate the relationship between self-efficacy and behavioral intentions, Spearman correlation analyses were conducted. Significant positive correlations were observed between overall travel-related self-efficacy and all behavioral intention items: BI3: Intention to keep using the free service ($r_s = 0.377$, $p < 0.001$); BI1: Substituting taxi trips with SSVS ($r_s = 0.268$, $p < 0.001$); BI2: Substituting private car use with SSVS ($r_s = 0.232$, $p < 0.05$); BI4: Intention to continue using the service even if charges are introduced ($r_s = 0.200$, $p < 0.05$). These results indicate that enhancing users' self-efficacy in daily transport can significantly strengthen their intentions to sustain the use of community-based electric ride-sharing services.

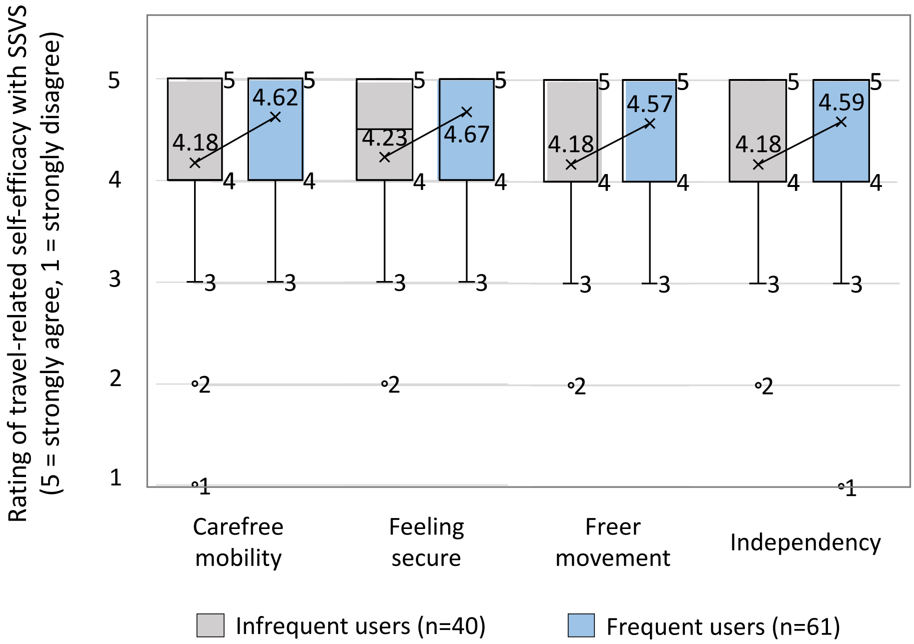

Figure 5.5 Group comparison between frequent and infrequent users on transport self-efficacy.

As previously reported (**Table 5.2**), users expressed a strong intention to use SSVS as a substitute for taxis (BI1, mean = 4.67) and private cars (BI2, mean = 4.40). Two additional items explored users' willingness to pay for the service under different conditions.

If the service remained free, 97.1% of respondents expressed an intention to use it, with 94.2% "strongly agree" and 2.9% "agree" responses. However, if the SSVS introduced a fee, the willingness to use dropped to 62.6%, with 21.2% "strongly agree" and 41.4% "agree" responses. This represents a 35.5% decrease in willingness to use when a cost is introduced, emphasizing the importance of maintaining affordability to sustain transport self-efficacy, particularly in community-based contexts.

5.6 Discussions and Conclusions

The chapter targets a strategic integration of digital technologies (Cyber) with community-driven approaches (Civitas) to facilitate the adoption of eco-friendly mobility options, specifically electric ride-sharing. In this context, the study examines how adapting digital solutions to meet community-specific needs and preferences can enhance the uptake of sustainable transport methods.

This study investigated a pilot project introducing community-based electric ride-sharing in Thailand, focusing on the pivotal role of travel-related self-efficacy in encouraging users to shift from existing travel modes to the promoted service. The findings highlight the importance of identifying meaningful goals during interventions to facilitate sustained behavioral change.

The study revealed that trust is a critical factor influencing perceived ease of use, attitudinal variables, and social norms. Trust acts as a control belief that can either enable or hinder behavior performance, consistent with prior research demonstrating its indirect effects through attitudes on adopting innovative mobility services (Chen, 2019). Furthermore, the division of attitudes into instrumental and hedonic dimensions successfully captured diverse aspects of consumer values. Both types of attitudes, influenced by perceived ease of use, indirectly impacted behavioral intention by mediating eudaimonic value and self-efficacy, thus enhancing the model's explanatory power.

Social norms were shown to positively influence hedonic attitudes, aligning with studies that link environmental motivations to positive emotional experiences when using emerging mobility services (Flores & Jansson, 2022). Importantly, eudaimonic value emerged as a critical mediating variable, significantly driving users' intentions to substitute private cars and taxis with community-based ride-sharing. Indirect positive effects from hedonic value, self-efficacy, and normative value reinforced the central role of eudaimonic value in sustaining behavioral intention. A study from Henderson, Knight, and Richardson (2013) support this findings that eudaimonic behaviors would lead to more experiences (i.e., keep using the service) through searching for greater meaning in activities.

The multi-group analysis results provide additional insights into the factors influencing sustained behavioral intention. The study categorized users based on their reliance on community-based electric ride-sharing as a primary mode for first- and last-mile travel. Frequent users primarily used the service, while infrequent users preferred private cars, taxis, or ride-hailing services for short-distance travel.

The findings revealed that trust significantly influenced instrumental attitude only among infrequent users, suggesting the importance of building a trustworthy service to enhance perceived usefulness for those with alternative mobility options. For frequent users, normative value played a unique role, fostering a sense of purpose and meaning during the intervention. Furthermore, frequent users exhibited higher self-efficacy in daily transport, which was strongly and positively correlated with behavioral intention, reinforcing the critical role of self-efficacy in sustaining behavior change. However, a significant decrease in intention was observed when users were asked to pay for the service. This aligns with Steg and Vlek's (2009) findings that moral obligations to act pro-environmentally are more effective for low-cost behaviors but have limited explanatory power when high behavioral costs or constraints, such as reducing car use, are involved.

This study contributes to the literature by deepening the understanding of the mechanisms underlying individuals' sustained intention to adopt sustainable mobility options. By integrating the Theory of Planned Behavior (TPB) with goal-framing theory, the research enhances theoretical frameworks in travel behavior intervention. The integrated model identifies key psychological factors that shape behavior while also providing insights into how behaviors evolve over time through goal pursuit.

A key contribution of this study is its emphasis on the mediating role of self-efficacy in connecting TPB and goal-framing theory. Consistent with Bandura's (1986) Social Cognitive Theory, high self-efficacy was found to motivate individuals during the goal-striving process and influence their progression in decision-making. This study demonstrates that external influences, such as beliefs about the consequences of specific actions (reflected in instrumental attitudes), primarily impact behavior through their effect on self-efficacy rather than directly.

By integrating TPB and goal-framing theory while highlighting the importance of self-efficacy, this research advances theoretical understanding and provides practical implications. The findings inform the design of effective interventions and strategies for promoting sustainable travel behavior, emphasizing trust, user-centered design, and the importance of affordable mobility to ensure long-term adoption.

5.6.1 Practical Implications

The research findings provide several insights for practical applications. Community-based electric ride-sharing can be effectively promoted in urban areas where the built environment enhances transit access and connectivity by linking destinations such as commercial facilities and services to transport hubs. Trust and perceived ease of use are essential conditions for users to adopt a new service. To build trust and ensure ease of use, it is crucial to offer a well-designed service from the outset. This can be achieved by employing well-trained, reliable drivers committed to road safety, implementing safeguards to protect users during travel, and providing user-friendly applications, such as intuitive reservation systems.

In the pilot project, increased demand led to a decline in service levels (e.g., longer waiting times). To sustain user intention, service providers must prioritize enhancing hedonic value. Along with ensuring riding comfort, the enjoyment and pleasure users derive from the service can be amplified through social norms. Promoting the environmental benefits of community-based electric ride-sharing can positively influence how users perceive the service, fostering experiential satisfaction and encouraging pro-environmental behavior.

Lastly, this study underscores the critical role of affordable transport services in strengthening travel-related self-efficacy, which is key to sustaining behavioral intention. Reinvesting development benefits across various sectors offers a promising strategy for funding affordable community-based transport initiatives. This approach channels gains from development projects back into the community, promoting overall growth and generating a positive societal impact. These findings have significant implications for policymakers, emphasizing the need for accessible and affordable transport services to support self-efficacy and encourage sustainable travel behavior.

Appendix 5A. Model estimation in PLS-SEM. Results generated by SmartPLS4.

Table A1. Hypothesis verification.

Path	Path coefficients	Standard deviation	T statistics	*P*
H1: TR→PE	0.286	0.082	3.475	***
H2: TR→HA	0.363	0.101	3.610	***
H3: TR→IA	0.291	0.094	3.114	**
H4: TR→SN	0.374	0.080	4.659	***
H5: PE→HA	0.312	0.075	4.145	***
H6: PE→IA	0.449	0.101	4.433	***
H7: IA→TS	0.780	0.049	15.790	***
H8: SN→HA	0.250	0.091	2.737	**
H9: HA→EV	0.145	0.094	1.540	ns (p=0.124)
H10: SN→NV	0.207	0.088	2.356	*
H11: TS→EV	0.328	0.088	3.751	***
H12: TS→NV	0.310	0.077	4.005	***
H13: NV→EV	0.364	0.098	3.711	***
H14: EV→BI	0.505	0.104	4.840	***
H15: NV→BI	0.205	0.089	2.289	*

Note: ns: non-significant; *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Table A2. Construct reliability and validity.

Construct	Item	Standard factor loading	Standard error	Cronbach's α	CR	AVE
Perceived ease of use	PE1	0.922	0.023	0.780	0.900	0.818
	PE2	0.887	0.053			
Trust	TR1	0.940	0.015	0.848	0.929	0.868
	TR2	0.923	0.021			
Social norm	SN1	0.878	0.045	0.761	0.892	0.806
	SN2	0.917	0.023			
Instrumental attitude	IA1	0.824	0.047	0.832	0.899	0.749
	IA2	0.915	0.020			
	IA3	0.855	0.027			
Hedonic attitude	HA1	0.862	0.028	0.728	0.847	0.650
	HA2	0.712	0.075			
	HA3	0.837	0.039			
Travel-related self-efficacy	TS1	0.932	0.018	0.949	0.967	0.907
	TS2	0.970	0.009			

	TS3	0.954	0.010			
Eudaimonic value	EV1	0.871	0.023	0.805	0.886	0.722
	EV2	0.905	0.024			
	EV3	0.767	0.068			
Normative value	NV1	0.875	0.059	0.799	0.906	0.828
	NV2	0.944	0.015			
Behavioral intention	BI1	0.914	0.023	0.763	0.894	0.808
	BI2	0.883	0.043			

Table A3. Discriminant validity.

Construct	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Perceived ease of use	**0.905**								
(2) Trust	0.286	**0.931**							
(3) Social norm	0.095	0.374	**0.898**						
(4) Instrumental attitude	0.533	0.420	0.175	**0.866**					
(5) Hedonic attitude	0.440	0.546	0.416	0.521	**0.806**				
(6) Travel-related self-efficacy	0.397	0.298	0.003	0.780	0.372	**0.952**			
(7) Eudaimonic value	0.423	0.518	0.197	0.544	0.466	0.458	**0.850**		
(8) Normative value	0.443	0.288	0.311	0.366	0.544	0.208	0.512	**0.910**	
(9) Behavioral intention	0.293	0.409	0.204	0.340	0.380	0.247	0.610	0.463	**0.899**

Appendix 5B. Results of moderating effect analysis

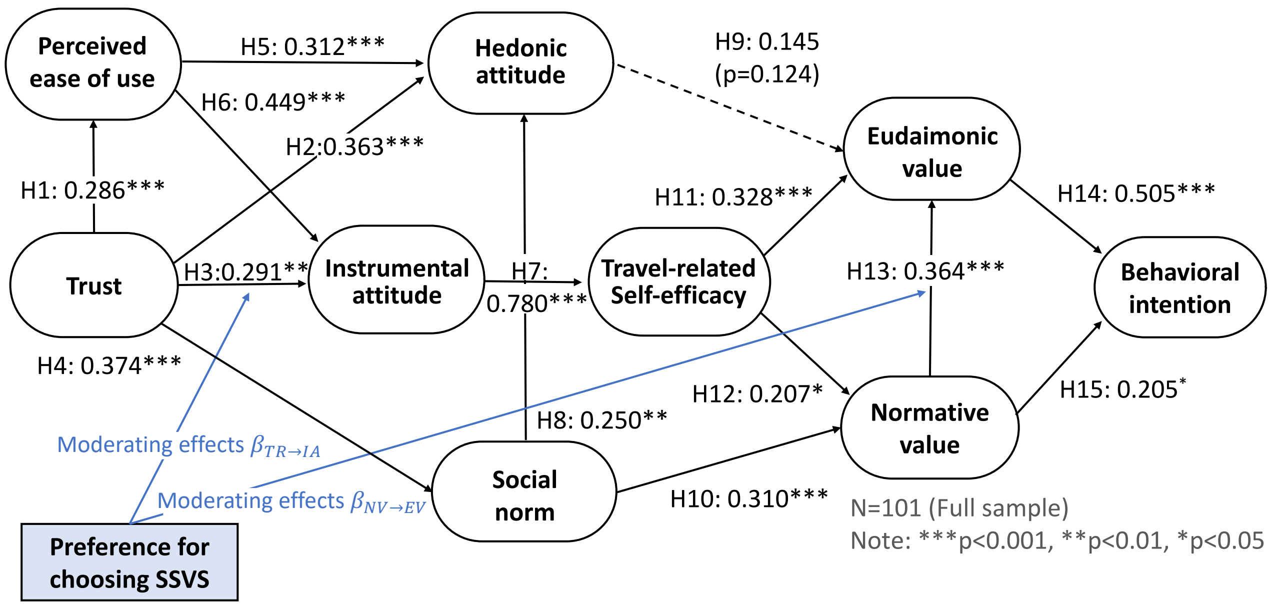

Figure B1. Estimated model in PLS-SEM – Mode preference as moderator.

Table B1. Moderating effect of mode preference for choosing SSVS on each path.

Moderating effects on each path	Estimate	Standard deviation	T statistics	*P*
H1: TR→PE	-0.131	0.199	0.657	ns
H2: TR→HA	-0.150	0.180	0.835	ns
H3: TR→IA	-0.362	0.177	2.049	p<0.05
H4: TR→SN	0.337	0.205	1.644	ns
H5: PE→HA	0.017	0.154	0.112	ns
H6: PE→IA	-0.113	0.164	0.690	ns
H7: IA→TS	-0.158	0.127	1.243	ns
H8: SN→HA	-0.054	0.199	0.272	ns
H9: HA→EV	-0.175	0.187	0.937	ns
H10: SN→NV	0.010	0.213	0.047	ns
H11: TS→EV	-0.203	0.191	1.059	ns
H12: TS→NV	0.010	0.213	0.047	ns
H13: NV→EV	0.395	0.197	2.009	p<0.05
H14: EV→BI	0.229	0.248	0.925	ns
H15: NV→BI	-0.223	0.173	1.287	ns

Note: The moderator is a dummy variable indicating a mode preference for selecting SSVS as 1.

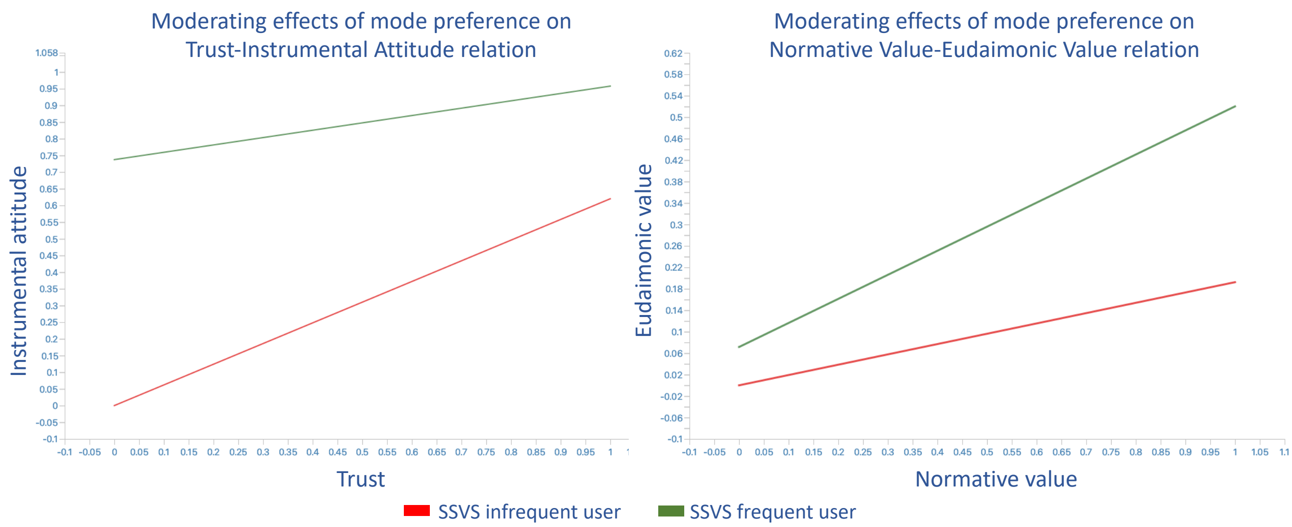

Figure B2. Moderating effects of the mode preference. Simple slope analysis by SmartPLS4.

In both figures of **Figure B2**, green represents the mode preference for choosing SSVS (i.e., frequent users), while red corresponds to the group of infrequent users. The upward-sloping lines from left to right indicate positive effects of trust (normative value) on instrumental attitude (eudaimonic value). Regarding the trust-instrumental attitude relationship, the positive effect exhibits a steeper slope among infrequent users, implying that increased trust yields amplified positive effects on enhancing instrumental attitudes. As for the normative value-eudaimonic value relationship, the positive effect displays a steeper slope among frequent users, suggesting that an enhancement in normative value results in a greater boost in eudaimonic values for frequent users. The results of the moderating effects analysis in PLS-SEM align with those of the multi-group analysis.

Appendix 5C. Group comparison

Table C1. T-test results between frequent users and infrequent user of SSVS.

Construct	Item	Frequent user (n=61)		Infrequent user (n=40)		T statistics
		Mean	S.D.	Mean	S.D.	
Perceived ease of use	PE1	4.26	0.874	4.05	0.959	1.149
	PE2	4.52	0.887	4.25	1.08	1.395
Trust	TR1	3.84	0.986	3.90	0.841	-0.337
	TR2	3.70	0.989	3.98	0.768	-1.540
	TR3	3.16	1.083	2.90	1.194	1.150
Social norm	SN1	1.84	1.227	2.13	1.159	-1.183
	SN2	2.52	1.689	3.13	1.343	-1.981*
	SN3	2.84	1.614	3.33	1.542	-1.515
Instrumental attitude	IA1	4.67	0.507	4.13	0.723	4.471***
	IA2	4.79	0.413	4.33	0.73	3.639***
	IA3	4.38	0.799	4.08	0.829	1.831
Hedonic attitude	HA1	3.93	0.834	3.65	0.864	1.653
	HA2	3.87	0.991	3.68	0.917	0.990
	HA3	4.08	0.802	3.88	0.757	1.296
Travel-related self-efficacy	TS1	4.62	0.582	4.18	1.01	2.542**
	TS2	4.67	0.569	4.22	0.947	2.685**
	TS3	4.57	0.644	4.18	0.844	2.687**
	TS4	4.59	0.761	4.18	0.844	2.568**
Eudaimonic value	EV1	4.41	0.739	4.20	0.608	1.556
	EV2	4.56	0.719	4.20	0.648	2.537**
	EV3	4.61	0.613	4.58	0.594	0.256
Normative value	NV1	4.26	0.772	4.03	0.891	1.420
	NV2	4.23	0.864	4.22	0.66	0.030
	NV3	4.23	0.824	4.13	0.939	0.590
Behavioral intention	BI1	4.75	0.623	4.55	0.714	1.518
	BI2	4.39	1.005	4.40	0.81	-0.035
	BI3	4.93	0.403	4.88	0.463	0.683
	BI4	3.64	1.184	3.70	0.853	-0.299

Note: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

6 Incorporating Personal Values in Mobility Choice Modeling and Examining Their Impact on Well-being

Summary: This chapter builds on the previous one by investigating and modeling how personal values influence decision-making across varying service levels in different mobility options. The rise of electric vehicles and car-sharing services is reshaping cities, fostering environmental sustainability, enhancing social equity, and driving cultural shifts toward more sustainable mobility. While personal values significantly affect mobility choices, the roles of authenticity and conformity remain underexplored. Conformity involves aligning with social norms to gain acceptance within social groups, whereas authenticity reflects making choices that align with one's values, even if they diverge from prevailing norms. Both factors influence individual well-being, yet their interplay is rarely examined in the context of mobility decisions.

To address this gap, this study explores how authenticity and conformity influence choices between car ownership and sharing, as well as preferences for gasoline versus electric vehicles. A survey conducted in Japan, incorporating responses from 1,200 participants across varying city sizes. Survey items included value-rational (hedonic), purpose-rational (instrumental), and normative values in mobility decisions, as well as the roles of authenticity, conformity, and happiness orientations.

Structural equation modeling (SEM) was employed to analyze the relationships among factors, while latent class choice modeling (LCCM) was used to understand how personal values affect mobility choices. The SEM results indicated that hedonic, instrumental, and normative values positively influence both eudaimonic and interdependent well-being. Eudaimonic well-being—happiness derived from self-accomplishment—was positively associated with authenticity but negatively related to conformity. In contrast, interdependent well-being—happiness derived from sharing with others—positively influenced both authenticity and conformity in mobility decisions.

The LCCM analysis further corroborated the significant impacts of personal values on mobility choices. These findings provide actionable insights for developing policies that respect and empower individual values and identities. By promoting inclusivity and equity in personal choices, this research contributes to creating a more human-centered and justice-oriented urban mobility system.

This chapter is a version of the following publication: Chou, C. C., Yoh, K., Kii, M., Doi, K. (2024). Owning or Sharing a Car: Analyzing the Role of Authenticity and Conformity in Mobility Decisions. International Conference: Urban Transitions 2024, Sitges, Spain.

6.1 Introduction

The rapid advancement of transportation technologies, such as alternative energy vehicles and shared mobility systems, is transforming urban landscapes. These innovations promote sustainability, equity, and livability by driving infrastructure development, changing mobility patterns, and influencing urban planning. Beyond structural impacts, transportation technologies can enhance individual and societal well-being by fostering empathy, positive emotions, and personal motivation in daily activities. As discussed in previous chapters, well-designed transport and mobility systems support psychological well-being and human potential, aligning with Calvo and Peters' (2014) insights on technology's role in promoting specific well-being factors, including positive emotions, self-awareness, and mindfulness, Etc.

As these technologies gain popularity, they hold the potential to reshape societal norms around transportation. The sharing economy, in particular, has introduced new ways of accessing resources and mobility solutions. While its benefits—such as increased accessibility and reduced environmental impact—are significant, some critics argue that the sharing economy may not genuinely embody the principles of sharing. Instead, it is often perceived as a strategic marketing construct designed to make profit-driven enterprises appear more socially acceptable and community-oriented (Arvidsson, 2018).

The practice of sharing resources and services, along with the collective use of mobility solutions, has the potential to influence user behavior in different ways. On one hand, it could encourage increased conformity with societal trends, as individuals adopt behaviors aligned with mainstream mobility practices (Cherchi, 2017). On the other hand, it might foster a stronger emphasis on authentic mobility choices, where individuals prioritize decisions that reflect their personal values, preferences, and lifestyles (Beverland & Farrelly, 2010). These tendencies may be driven by intrinsic factors, such as values and aspirations, or by extrinsic benefits, including the expanded availability of electric vehicles (EVs) and shared mobility services within a community. Such dynamics highlight the complex interplay between individual agency and external influences in shaping travel behavior in the evolving mobility landscape. However, the relationships between these service attributes and personal values remains unclear and warrants further exploration.

Building on previous discussions about the influence of personal values on individual choices, this study examines how personal values shape decision-making across varying levels of service in different mobility options. It explores the relationship between travelers' mobility preferences and their orientation toward happiness, viewed as a guiding principle for desired lifestyles and well-being. Specifically, the study investigates how users evaluate mobility system attributes and how personal attitudes influence choices, including preferences for gasoline vehicles, electric vehicles, car-sharing, and ride-sharing services. Furthermore, it examines how adopting shared and collective services impacts decision-makers' sense of happiness. To address these questions, a survey conducted in Japan collected 1,200 valid responses, considering city size and regional conditions.

6.2 Hypothesized Model and Formulation

6.2.1 Relationships between Attitudes, Happiness, and Mobility Lifestyles

The underlying hypotheses in this chapter is rooted in the theory of value-oriented and virtue-oriented behaviors, which propose that individuals act in ways that align with their pursuit of happiness. In behavioral science, value-oriented behaviors are actions driven by the pursuit of personal or collective goals, guided by individual or societal values. In contrast, virtue-oriented behaviors are motivated by moral virtues, such as compassion and altruism—qualities considered morally good or desirable. Both types of behavioral principles are crucial for understanding how people make decisions and act in various situations. These principles often intersect, as individuals may seek to achieve happiness by aligning their actions with both their values and virtues.

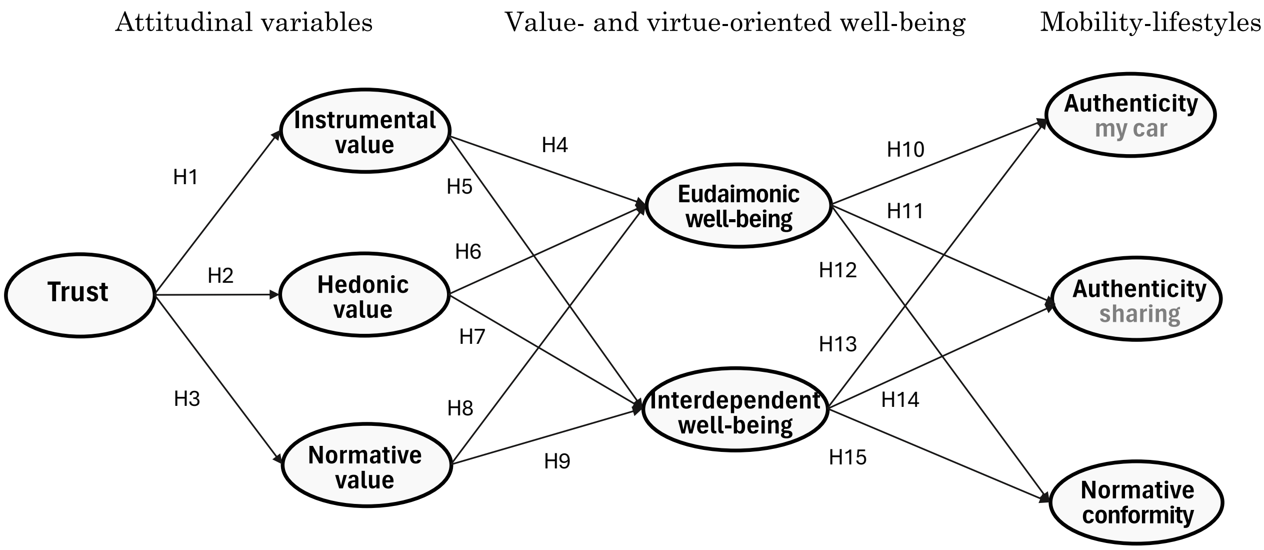

Figure 6.1 Hypothesized structural relationships among attitudes, happiness orientations, and mobility decisions.

In the hypothesized model (**Figure 6.1**), eudaimonic and interdependent well-being are identified as forms of value- and virtue-oriented well-being that influence individuals' behaviors in daily life. ***Eudaimonic well-being*** refers to the happiness that comes from living a meaningful life, fulfilling one's potential, and adhering to deeply held values (Waterman et al., 2010). On the other hand, ***interdependent happiness*** is derived from strong, positive relationships with others and a sense of belonging and social harmony (Uchida et al., 2008). These factors may serve as behavioral principles that mediate the relationships between attitudes toward services and desired lifestyles regarding daily mobility.

Attitudinal variables toward service attributes in the hypothesized model build on the discussions and findings from previous chapters. These attitudes, as adapted from Schuitema et al. (2013), are shaped by consumer value creation, capturing various aspects of attitudes toward using EV and emerging sharing services. ***Instrumental value*** refers to the functional utility of a service, such as effectiveness and safety, while ***hedonic value*** involves the positive emotional experiences it provides, like enjoyability and pleasure. In the context of new environmentally-friendly transport services and technologies, *normative values* and trust are also identified as important attitudes. ***Normative value***, which influences social norms in the Theory of Planned Behavior model, pertains to beliefs about what is considered normal or acceptable behavior in society. Additionally, ***trust*** is a crucial factor in shaping individuals' intentions toward new mobility services, as it enhances perceived ease of use by reducing uncertainty and improving perceived reliability. These attitudes play significant roles in the adoption of electric mopeds, scooters, and small cars (Chen, 2019; Kopplin et al., 2021).

Two additional factors, authenticity and conformity, are central to the hypotheses and actively influence the decision-making process. ***Conformity*** involves aligning with social norms to gain acceptance within social groups, while ***authenticity*** means making choices that are true to one's values, even if they go against prevailing norms. For example, an individual may choose a service because it aligns with their authentic preferences or because it conforms to societal or policy-driven trends. In mobility choices, this dynamic could manifest as a preference for car ownership due to a sense of pride and preference or as an inclination toward sharing driven by societal or environmental considerations.

6.2.2 Modeling Mobility Choice Considering Personal Values

In the hypothesized structural model, orientations in happiness (e.g., eudaimonic well-being and interdependent well-being) and mobility lifestyles (conformity and authenticity) are expected to significantly influence daily mobility choices. This study further investigates their impact on decision-making. While previous research on transport service preferences has commonly employed discrete choice models based on the theory of rational utility—where utility is determined by service attributes and socioeconomic factors—this assumption of purely rational behavior has been increasingly questioned. Psychological factors, such as attitudes and perceptions, often interact with rational considerations, playing a critical role in shaping individual decisions.

To address the limitations of purely rational models, the Latent Class Choice Model (LCCM) builds upon the discrete choice model by dividing consumers into several latent classes based on their responses (Vij and Krueger, 2017). Each class may prioritize different attributes, such as cost, time, or convenience, when making choices. LCCM is particularly useful for capturing the heterogeneity among individuals and groups, leading to more accurate predictions of behavior. As illustrated in **Figure 6.2**, the LCCM framework consists of both a class membership model and a class-specific choice model. The model estimates both the probability that an individual belongs to a particular latent class and the likelihood that they will choose a specific option based on the preferences associated with that class. The formulation is elaborated as follows.

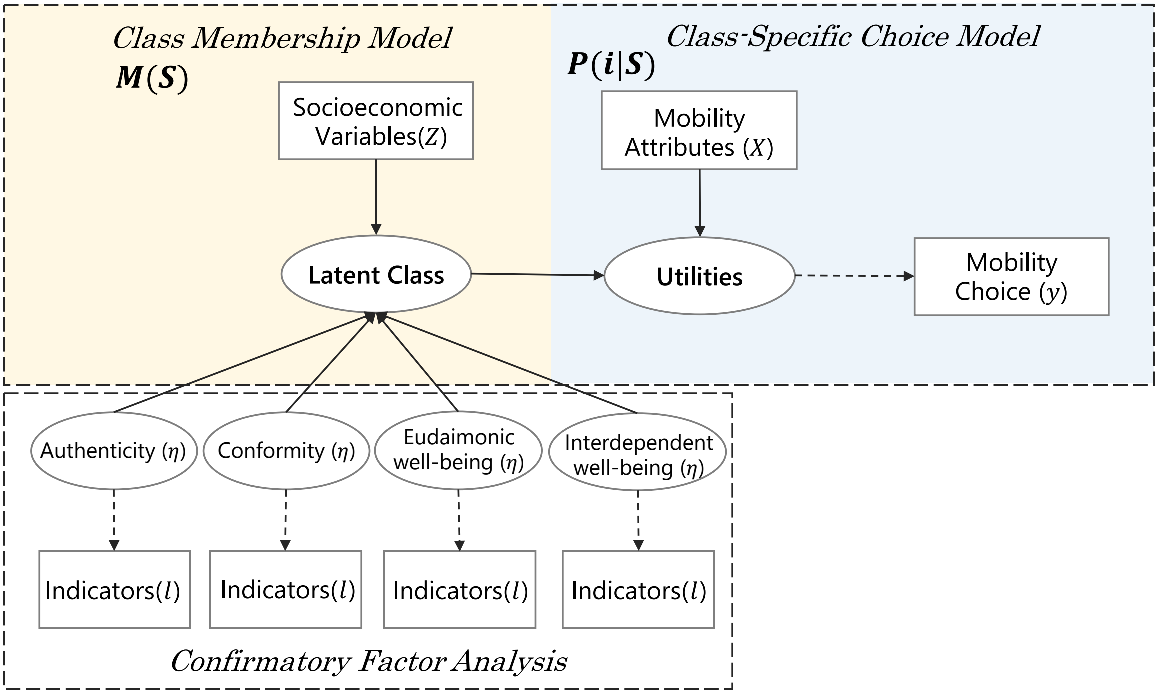

Figure 6.2 LCCM framework for analyzing heterogeneous travel decision-making.

The class-specific choice model

In the context of mobility choice, a utility function ($U_{nti|s}$) for traveler n belongs to class s (s = 1, 2, ..., S) when choosing an alternative i of scenario t is described below:

$$U_{nti|s} = \beta'_s X_{nti} + \varepsilon_{nti|s} \tag{6.1}$$

where X_{nti} is a vector of service attributes, such as travel time, cost, CO_2 emissions, and booking reliability; β_S is a vector of unknown class-specific parameters; and $\varepsilon_{nti|s}$ represent a random error.

The class membership model

The probability of mobility alternative i in scenario t being chosen by traveler n in class s has the following equation:

$$P_{nt}(y_n = i|s) = \sum_{s=1}^{S} P_{nt}(i|s) \cdot M_n(s), \tag{6.2}$$

where $P_{nt}(y_n = i|s)$ represents the conditional probability that traveler n, belonging to class s, chooses alternative i in scenario t. The class membership function $M_n(s)$ denotes the probability that traveler n belongs to class s. Assuming both probabilities follows a multinomial logit (MNL) model formulation, equation 6.2 can be expressed as follows:

$$P_{nt}(y_n = i|s) = \sum_s \{ \frac{\exp(\beta'_s X_{nti})}{\sum_{i \in C_{nt}}^{I} \exp(\beta'_s X_{nti})} \cdot \frac{\exp(\gamma'_s Z_n + \lambda'_s \eta_n)}{\sum_{s=1}^{S} \exp(\gamma'_s Z_n + \lambda'_s \eta_n)} \}, \tag{6.3}$$

where Cnt is the choice set in scenario t for traveler n, which includes alternative j. The parameter β_S and $Xnti$ are as previously defined; Zn is a vector of covariates of class membership function, including demographical characteristics and prior experience with certain mobility alternative, and γ_S is a corresponding parameter vector for class s. η_n represents a vector of latent variables, measured by their factor scores from Confirmatory Factor Analysis (CFA) (as illustrated later), and λn is the associated parameter vector.

The latent variable reflecting its associated indicators is represented as follows:

$$Iqn = \eta_{ln}\alpha q + \upsilon qn, \; q = 1,2,\cdots Q, \tag{6.4}$$

where Iqn indicates that traveler n responds to the q^{th} indicator within latent variable l; αq is the corresponding standardized factor loadings, and Yqn is a random error following a standardized normal distribution. Q is the total number of indicators.

6.3 Materials and Methods

6.3.1 Questionnaire Design

The questionnaire contained three parts: socioeconomic and travel behavior characteristics, attitudes toward mobility options, and the experimental design of stated preferences.

This study collected participants' socioeconomic characteristics, such as gender, age, and the number of available cars in the household, as well as travel behavior characteristics, such as driving frequency and experiences with electric vehicles, car sharing, and ride sharing services.

The survey items related to attitudes were based on previous literature, with modifications to the measurement scales for all constructs to fit the research context. Each construct in the questionnaire comprised a set of items presented in a five-point Likert scale format, where respondents indicated their level of agreement or disagreement (1 = "strongly disagree" and 5 = "strongly agree") with the item statements. The analysis of personal values influencing attitudes in mobility choices builds on our published results in Chapter 5 (Chou et al., 2024). These values include instrumental (3 items), hedonic (3 items), and normative values (3 items), along with trust (2 items). Normative conformity, as defined by Cherchi (2017), was introduced in this study with 2 proposed items. Authenticity was measured using 4 items based on Beverland and Farrelly (2010), while interdependent well-being was assessed with 3 items following Uchida et al. (2008). Finally, eudaimonic well-being was measured with 3 items, as referenced in Chou et al. (2024).

The stated preference experiment was designed to investigate participants' preferences in mobility choice for their primary household mobility. These mobility options included household-owned gasoline vehicles, household-owned electric vehicles (EVs), car sharing services, and ride sharing services. **Table 6.1** shows the levels of five attributes and the level of services for each option. The general cost, calculated during the data preparation stage from initial costs, maintenance costs, and driving costs, was used for model estimation. Additionally, booking reliability, defined as 100% minus the reservation failure rate, was also used for model estimation.

Table 6.1 Attributes and levels of service of mobility options.

Attributes	Levels			
	Gasoline vehicle	Electric vehicle	Car sharing	Ride sharing
1. Initial cost (thousand JPY)	2500,	3000, 4000	0	0,
2. Maintenance cost (thousand JPY)	30	10	0	0
3. EV battery replacement cost every 8 years (thousand JPY)		300, 1000		
4. Driving cost (JPY)	5, 8.4, 10 (per km)	3.3, 8 (per km)	1500, 2000, 2500 (per hour)	150, 300, 400 (every 15 min)
5. CO_2 emissions (g/km)	70, 160	70, 100	160	80, 160
6. Reservation failure risk (%)	0	0	5, 10, 15	5, 10, 15

6.3.2 Data Collection and Sample Profile

A self-administered questionnaire survey was conducted in Japan from February 13 to 19, 2024. The survey was carried out by a market research agency to ensure wide participation through online methods. The target respondents were people who drive at least once a month and have access to a car. The survey yielded 1,200 valid responses, ensuring an even distribution across three identified city sizes. Specifically, in this study, a small city is defined as having a population of 100,000 or less, a medium city as having a population between 100,000 and 500,000, and a large city as a government ordinance city with a population of at least 500,000. **Table 6.2** presents the sample profile. **Table 6.3** summarizes the characteristics of respondents by city size.

Table 6.2 Sample profile.

Characteristics	Sample size (n=1200)	Percentage (%)
Gender		
Male	809	67.4
Female	389	32.4
Prefer not to answer	2	0.2
Age		
20-29	23	1.9
30-39	123	10.3
40-49	222	18.5
50-59	326	27.2
60-64	185	15.4
65-69	154	12.8
70-79	167	14.0
Driving frequency		
5 or more days a week	368	30.7
3-4 days a week	209	17.4
1-2 days a week	399	33.3
More than once a month	224	18.7
Available car to use		
Have a car that can be freely used	570	47.5
Shared within the household	500	41.7
Registered with a local car share	130	10.8

Table 6.3 Respondents' characteristics by city size.

Variable	Category	Large city (n=400)	Medium city (n=400)	Small city (n=400)
Driving frequency	5 or more days a week	14.3	36.8	41.0
	3-4 days a week	15.8	18.0	18.5
	1-2 days a week	35.3	35.3	29.3
	More than once a month	34.8	10.0	11.3
Available car	Have a car that can be freely used	35.0	53.8	53.8
	Shared within the household	35.0	45.0	45.0
	Registered with a local car share	30.0	1.3	1.3
Familiarity with EVs	Used many times	4.5	4.0	1.8
	Used a few times	11.0	3.0	4.5
	Know about it but haven't use it	74.8	77.5	80.0

	Heard about it	8.3	11.5	12.0
	Heard for the first time	1.5	4.0	1.8
	Respondents with usage experience	*15.5*	*7.0*	*6.3*
Familiarity with car sharing	Used many times	23.8	1.5	0.5
	Used a few times	9.8	1.5	1.8
	Know about it but haven't use it	52.0	73.0	70.3
	Heard about it	13.3	18.3	25.0
	Heard for the first time	1.3	5.8	2.5
	Respondents with usage experience	*33.5*	*3.0*	*2.3*
Familiarity with ride sharing	Used many times	2.0	0.5	1.0
	Used a few times	2.5	0.5	0.5
	Know about it but haven't use it	51.5	47.8	45.0
	Heard about it	30.5	25.3	28.8
	Heard for the first time	13.5	26.0	24.8
	Respondents with usage experience	*4.5*	*1.0*	*1.5*

6.3.3 Data Analysis

This study applied structural equation modeling (SEM) with the maximum likelihood estimates to address a series of interrelated dependence relationships among latent variables and between latent constructs. The data analysis followed a two-stage approach. Before proceeding with the hypotheses verification, the scale validation was examined by conducting a confirmatory factor analysis (CFA).

For analyzing citizens' mobility preferences and choices, we first estimated a Multinomial Logit (MNL) model to serve as a baseline. Subsequently, a latent class choice model (LCCM) was developed by segmenting respondents into a finite number of classes. The optimal number of latent classes in the model was determined using several information criteria, such as log-likelihood, Akaike Information Criterion (AIC), and Bayesian Information Criterion (BIC).

6.4 Results and Discussions

6.4.1 Attitudes toward Mobility Options

Table 6.4 shows the descriptive statistics, including item means and standard deviation. **Table 6.5** presents the CFA results of each latent construct. The estimated model showed good fit indices according to CFI = 0.961, TLI = 0.949, RMSEA = 0.050, GFI = 0.944, AGFI = 0.921, X^2 (194) = 783.554, X^2/df = 4.03.

Table 6.4 Descriptive statistics.

Constructs and items		Mean	S.D.
Instrument values (IV)			
IV1	Traveling at a low	4.09	0.953
IV2	Being able to drive or get a ride close to my destination	4.24	0.879
IV3	Having the freedom to travel according to my own schedule	4.36	0.853
Hedonic values (HV)			
HV1	Enjoying the driving or riding time	3.61	1.071
HV2	Being to ride with someone and have conversations inside the vehicle	3.07	1.215
HV3	Being able to ride in a vehicle I like	3.45	1.133
Normative values (NV)			
NV1	Sharing vehicles is more beneficial for the community, including myself, than owning a private car	3.07	0.979
NV2	Sharing vehicles places less burden on the country or region where I live than owning a private car.	3.17	0.963
NV3	Sharing vehicles places less burden on future generations than owning a private car.	3.18	0.979
Trust (TR)			
TR1	Being able to travel safely with a low risk of accidents	4.21	0.919
TR2	Having a trustworthy vehicle or service	4.15	0.945
Eudaimonic well-being (EW)			
EW1	It's important to enjoy my life.	4.11	0.841
EW2	It's important to spend each day meaningful.	3.97	0.868
EW3	It's important to me to find fulfillment.	4.14	0.745
Interdependent well-being (IW)			
IW1	It's important not only for myself but also for those close to me to be happy.	3.88	0.796
IW2	I feel happy when those around me are happy.	3.71	0.848
IW3	Helping someone solve their problems lightens my heart and makes me feel happy.	3.71	0.840
Authenticity: owing a car (AC)			
AC1	Regardless of how others feel, I choose the vehicle or service that I like.	2.56	1.058
AC2	Since I like driving, I want to own my own vehicle.	3.96	1.090
Authenticity: sharing service (AS)			
AS1	Car sharing suits me/reflects my preferences.	3.96	0.903
AS2	Ride sharing suits me/reflects my preferences.	3.66	1.086
Normative conformity (NC)			
NC1	Because reducing environmental impact is being promoted globally, I feel I must use vehicle sharing.	2.35	1.174
NC2	If car sharing becomes popular in the future, I would like to use it.	2.22	1.070

Table 6.5 CFA results of survey items.

Constructs	Items	Factor loadings	Cronbach's α	CR	AVE
Instrument values	IV1	0.539	0.76	0.78	0.54
	IV2	0.859			
	IV3	0.807			
Hedonic values	HV1	0.830	0.80	0.80	0.57
	HV2	0.685			
	HV3	0.768			
Normative values	NV1	0.855	0.94	0.94	0.84
	NV2	0.959			
	NV3	0.934			
Trust	TR1	0.875	0.88	0.88	0.78
	TR2	0.889			
Eudaimonic well-being	EW1	0.866	0.84	0.85	0.65
	EW2	0.814			
	EW3	0.720			
Interdependent well-being	IW1	0.716	0.85	0.85	0.66
	IW2	0.867			
	IW3	0.840			
Authenticity: owing a car	AC1	0.593	0.55	0.56	0.40
	AC2	0.645			
Authenticity: sharing	AS1	0.952	0.89	0.90	0.82
	AS2	0.844			
Normative conformity	NC1	0.847	0.85	0.85	0.74
	NC2	0.871			

6.4.2 Structural Equation Modeling Results

The hypothesized structural model was estimated to examine the relationships between the constructs. The model demonstrated a good fit with the sample data, as indicated by the goodness-of-fit indices ($X^2(212) = 1255.516$, $X^2/df=5.92$, CFI = 0.930, TLI = 0.917, GFI = 0.915, AGFI = 0.889, RMSEA = 0.064). **Figure 6.3** shows the estimated model with the standardized path coefficients and significant levels. Fourteen out of the fifteen hypotheses in the model were empirically supported, except for the effects of eudaimonic well-being on authenticity in choosing sharing services ($p = 0.104$).

Trust was found to have significant and strong positive effects on instrumental value ($\beta = 0.50$, $p < 0.001$) and hedonic value ($\beta = 0.74$, $p < 0.001$), as well as a significant but weaker positive effect on normative value ($\beta = 0.06$, $p < 0.05$). All three values—instrumental, hedonic, and normative—had significant positive effects on both eudaimonic well-being and interdependent well-being. Among the three types of values, instrumental value showed a stronger correlation with eudaimonic well-being ($\beta = 0.33$, $p < 0.001$), while hedonic value had a stronger correlation with interdependent well-being ($\beta = 0.23$, $p < 0.001$).

The respondents' orientations toward happiness significantly influenced their mobility preferences and decisions. Positive correlations were observed between interdependent well-being and both authenticity and normative conformity, suggesting that individuals who derive happiness from social connections and community tend to make mobility choices that align both with their true self and the norms of their society. The path coefficients were ranged from 0.10 to 0.17, showing no significant difference in the strength of these correlations. This might suggest a balance between personal preferences and social expectations in their mobility decisions.

Notably, eudaimonic well-being was positively correlated with authenticity in the decision to own a car ($\beta = 0.47$, $p < 0.001$) but negatively correlated with normative conformity ($\beta = -0.13$, $p < 0.001$). The strong positive correlation between eudaimonic well-being and authenticity in the choice to own a car suggests that individuals who pursue personal development and fulfillment (i.e., eudaimonic well-being) prefer choices that they perceive as more authentic to their values and less influenced by external factors. In this context, owning a car might be viewed as a more authentic choice that supports their personal or professional aspirations, reflecting a direct expression of their identity and values. Conversely, the significant negative correlation indicates that individuals high in eudaimonic well-being are less likely to conform to societal norms that dictate mobility choices, such as the increasing trend towards using sharing services. This suggests that for these individuals, personal fulfillment comes from making decisions that are true to themselves rather than following popular or societal expectations.

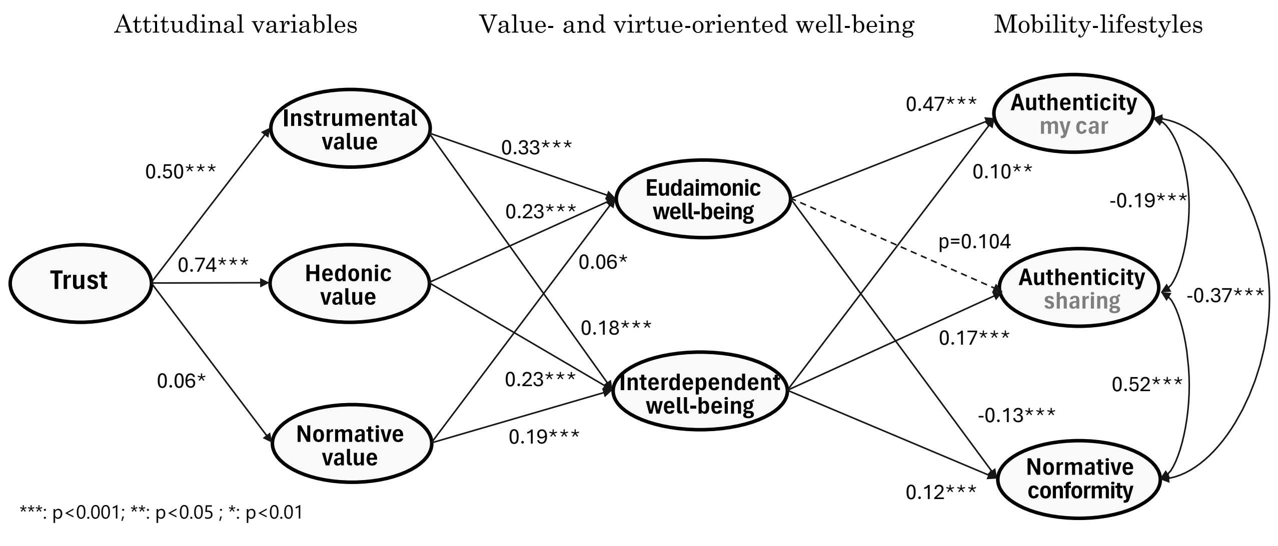

Figure 6.3 The estimated hypothesized model.

6.4.3 Latent Class Choice Model Estimation

This study first estimated the Multinomial Logit (MNL) model to assess citizens' preferences for household mobility options (as shown in **Table 6.6**). The three alternative-specific constants (ASCs) were specified relative to the reference alternative, "owning a gasoline vehicle." The negative estimates of the ASCs for both car sharing and ride sharing suggest that respondents generally prefer owning a car. The goodness-of-fit values for the models are approximately 0.21, indicating an acceptable fit (Domencich & McFadden, 1975), with the models explaining 21% of the variation in the outcome variables, respectively. Although all attributes were statistically significant, they did not exhibit the expected signs.

Table 6.6 MNL estimation results of the mobility choice.

Variables		Coeff.	t value	*p*
ASC Constant	EV owing	0.76	6.12	***
	Car sharing	-2.56	-17.82	***
	Ride sharing	-1.63	-10.44	***
SP Attributes	General cost	0.10	15.29	***
	CO_2 emissions	0.23	16.15	***
	Booking reliability	-0.14	-8.16	***
Log Likelihood		-1976.2		
McFadden R^2		0.21436		
Likelihood ratio test (chisq)		1078.4 (p < 0.001)		

The LCCM was employed to explore whether different groups prioritize various attributes when making mobility choices, with a focus on their personal values. The model estimation results for primary mobility choices are presented in **Table 6.7**, and the estimated mode share for each alternative is illustrated in **Figure 6.4.** The increase in log-likelihood from -1976.2 to -1833.5 indicates that the LCCM model has improved over the MNL model in terms of how well it explains the observed data.

Respondents were classified into three classes, comprising 73.6% (Class 1), 4.4% (Class 2), and 22.0% (Class 3) of the sample. Class 1 was treated as the reference class in the class-specific choice model, with the coefficients of its membership function constrained to zero.

Table 6.7 LCCM results for primary household mobility.

Variable		Class 1 Model:			Class 2 Model:			Class 3 Model:		
		Coef.	T	p	Coef.	T	p	Coef.	T	p
Class-specific choice model										
ASC Constant	EV owing	0.60	2.55	*	15.51	1.00	ns	0.79	2.89	**
	Sharing	-560.0	-0.06	ns	**-785.7**	**-7.70**	***	9.02	4.43	***
SP Attributes	Cost	0.06	5.70	***	**-0.51**	**-6.93**	***	**0.06**	**7.13**	***
	Time	**-2.42**	**-156.9**	***	**-10.5**	**-16.65**	***	**0.08**	**8.32**	***
	CO_2 emissions	0.25	9.06	***	1.33	0.78	ns	0.04	1.50	ns
	Reliability	64.0	0.07	ns	**98.4**	**8.00**	***	-0.83	-3.45	***
Class membership model										
Latent Variables	Authenticity				0.96	1.61	ns	**-0.42**	**-2.78**	**
	Conformity				**1.78**	**4.50**	***	**0.95**	**8.14**	***
	Eudaimonic well-being	*Reference*			0.11	0.22	ns	**0.21**	**1.80**	**p=0.07**
	Interdependent well-being				0.19	0.52	ns	**0.27**	**2.45**	*
Characteristics	EV experience				1.35	2.32	*	1.17	4.50	***
% of Respondents		73.6% (n=883)			4.4% (n=53)			22.0% (n=264)		

Note: * < 0.05. ** < 0.01. *** < 0.001; "ns" indicates nonsignificant values. *AIC: 3727.0, BIC: 3900.5*

Class 1, which represents 73.6% of the sample, exhibited a stronger preference for owning a car over using shared mobility options. The significant and robust t-values indicate that respondents in this class prioritize time efficiency in their daily mobility choices. Essentially, these respondents value having control over their time and find car ownership better aligns with this priority. When examining mode share probabilities, this class showed minimal likelihood of choosing car-sharing or ride-sharing services, consistent with their emphasis on time efficiency.

Class 2 exhibits rational decision-making with a focus on service attributes like time, cost, and booking reliability. These factors emerged as the most influential factors in their choices. Among the latent variables, conformity was the only significant factor, positively affect their decisions, suggesting they are influenced by social norms to some context. This class demonstrated a high probability of choosing an EV (68.8%) over a gasoline vehicle (4.7%), indicating a strong preference for newer, perhaps environmentally friendly technology.

Class 3, accounting for 22.0% of the sample, showed unexpected signs for SP attributes, such as positive coefficients for cost and time and a negative coefficient for reliability. However, the alternative-specific constant (ASC) suggests a stronger preference for both EV ownership and sharing. This could indicate that members of this class may perceive the higher cost and time associated with EVs and shared mobility as a trade-off for other valued attributes (like environmental benefits or newer technology). The coefficient direction aligned with because sharing options are perceived to have both higher time requirements and disadvantages in reliability. Significant positive values for conformity and interdependent well-being suggest a greater openness to sharing, influenced by social connections and community values. This class also shows higher levels of eudaimonic and interdependent well-being, further aligning with preferences for shared mobility options due to their broader social and personal fulfillment values.

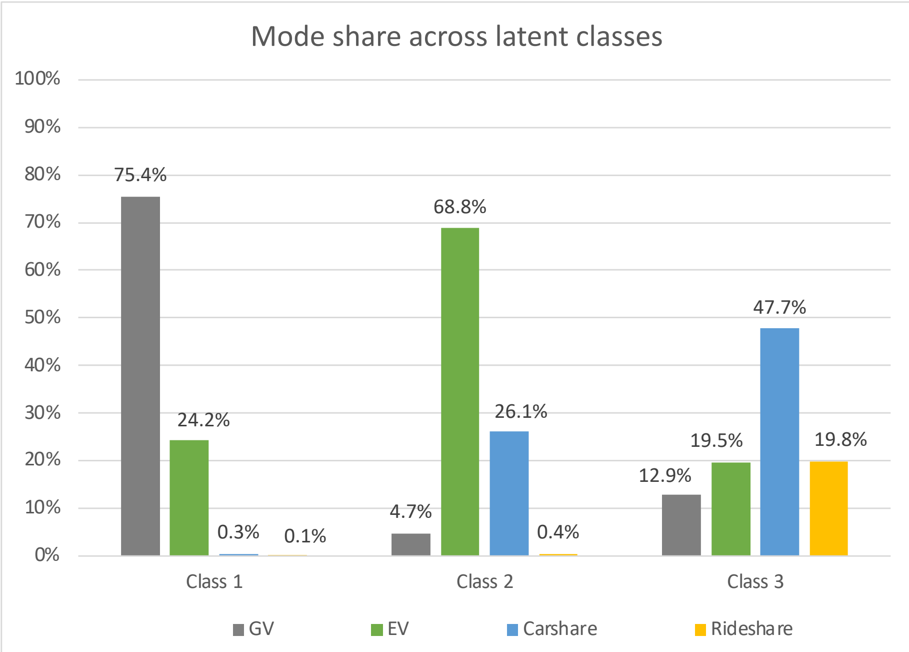

Figure 6.4 Estimated mode share for primary mobility choice.

Notably, both Class 2 and Class 3 demonstrated significant effects of conformity, yet their orientations toward happiness markedly diverged. Class 3, characterized by high levels of eudaimonic and interdependent well-being, showed a significant negative value in authenticity. Contrary to other classes that equate car ownership with personal identity and authenticity, Class 3 aligns sharing options with their values, showing a greater openness to car sharing and ride-sharing services. This suggests that for Class 3, engaging in shared systems and adhering to group norms not only enhances their sense of self but also contributes to their overall happiness.

In contrast, Class 2, while also embracing conformity, primarily focuses on EV ownership, which reflects a distinct alignment of values and preferences. Their emphasis on time efficiency intensifies this tendency. Overall, these results reveal significant taste heterogeneity across the classes, effectively captured by the LCCM model.

6.5 Conclusions

This chapter investigates how personal values influence mobility choices and their implications for well-being, employing Structural Equation Modeling (SEM) and Latent Class Choice Modeling (LCCM) to analyze preferences for car ownership, car-sharing, and ride-sharing options. The findings underscore the nuanced role of individual values in shaping mobility decisions and their orientation toward happiness. The results underscore the importance of tailoring policies and services to respect diverse value systems, promote equity, and enhance user satisfaction in urban mobility systems. By capturing the heterogeneity of user preferences, this chapter provides valuable insights for designing inclusive and user-centered policies that align with evolving societal and environmental goals.

The SEM results reveal that individuals who value eudaimonic well-being prioritize authenticity and are more inclined to own a car, viewing it as a direct reflection of their personal identity. In contrast, the LCCM results identify distinct classes with varying values and preferences. Specifically, Class 3, despite a negative score in authenticity, does not perceive sharing as diminishing their personal identity. Instead, they find value in conforming to social norm and participating in shared mobility systems, presenting higher eudaimonic well-being.

Both modeling approaches indicate that people's orientations toward happiness significantly influence their mobility decisions. Individuals seeking fulfillment through personal achievements prefer options that align with their values, such as car ownership. Conversely, those who values the happiness of others are more receptive to shared mobility solutions. This aligns with Hommerich et al. (2022), who found that a belief in reciprocity is closely interrelated with interdependent happiness, where people more concerned with others' happiness rely heavily on social affiliation and connection. Similarly, Oarga et al. (2015) observed that reciprocal norms are particularly beneficial for well-being in societies that endorse shared social norms of reciprocity. This finding emphasizes the importance of reciprocal norms for those with an interdependent, rather than independent, well-being. The findings from Hommerich et al. (2019) also align with our results, pointing out that the sharing economy is supported by egoistic beliefs, norms of reciprocity, and social values. They noted that self-identification negatively impacts the use of sharing economy services.

These findings suggest some implications. Those oriented towards eudaimonic well-being appear to prioritize personal authenticity over social conformity, suggesting a potential target demographic for marketing mobility solutions that are branded as being reflective of personal values and aspirations. Conversely, strategies for promoting shared mobility services might be more effective if they are framed in ways that appeal to interdependent aspects of well-being, emphasizing community benefits and social norms. Policymakers can use these insights to promote sustainable mobility. In areas where shared mobility aligns with community-oriented values, policies could focus on improving the reliability of sharing services. Conversely, in regions where car ownership is valued, policies can focus on promoting more sustainable personal mobility, such as encouraging EV adoption.

7 Conclusions

7.1 Answer to Research Questions

An overview on this research is provided to answer to each research questions.

RQ1: How does users' spatial experience affect their urban travels?

From an urban spatial design perspective, ***Chapter 2*** conceptualizes a community-centered design approach aimed at creating resilient and self-sufficient cities. This approach emphasizes resource-efficient strategies that capitalize on spatial opportunities offered by urban void spaces within transportation infrastructure.

The case studies illustrate how well-connected spatial environments around public transport infrastructure can enhance compassionate mobility, linking urban cores while promoting individual health, well-being, and community resilience. A prominent example is the utilization of continuous void spaces beneath elevated railways, created through multi-level railway crossing projects integrated with urban redevelopment. These underutilized spaces, located in dense urban areas, offer significant potential for adaptive planning. Beyond their functional connectivity, the symbolic value of elevated railways and their intuitive flow lines present opportunities to revitalize and enrich urban areas along railway corridors.

Historically perceived as "walls" that divide cities, elevated railways have the potential to transform into dynamic urban hubs. Continuous void spaces between railway stations can shift the focus from vehicles to people, creating vibrant, pedestrian-friendly environments that accommodate walking, leisure, and community engagement. These spaces are envisioned as healthy, inclusive urban corridors that not only enhance livability but also serve as critical axes for building sustainable and resilient cities.

From the perspective of mobility system design, ***Chapter 3*** explores the role of spatial cognition in mobility travel behaviors, drawing on findings from a pilot service involving small-format electric vehicles equipped with battery-sharing solutions. The results provide three key insights: (1) *Accumulating spatial experience enhances spatial knowledge*, improving users' ability to navigate urban environments more effectively. (2) *Better spatial knowledge improves user satisfaction and enjoyment.* Users with stronger cognitive distance knowledge demonstrated higher expectations for traveling across larger areas and expressed fewer concerns about charging issues. These users also displayed a more accurate understanding of the proximity and availability of charging stations, reducing anxiety about battery depletion. This aligns with research showing that psychological proximity enhances perceived control (Huang & Zhang, 2023). (3) *An interaction effect exists between cognitive distance and direction knowledge.* Participants with improved cognitive distance reported lower satisfaction with the driving range when their cognitive direction also improved, reflecting a treadmill effect—where heightened aspirations reduce satisfaction. This finding underscores the importance of developing adaptable mobility solutions to accommodate diverse travel needs.

Together, these insights emphasize the critical role of spatial experiences in shaping urban travel behaviors. By enhancing spatial knowledge, mobility services can increase user satisfaction, reduce concerns, and improve overall system efficiency, contributing to more inclusive and sustainable urban mobility systems.

RQ2: How can daily mobility be secured in motorcycle-dependent areas?

Securing daily mobility in motorcycle-dependent areas requires a multifaceted approach that addresses safety, infrastructure, and behavioral challenges. ***Chapter 4*** applies psychometrics and cultural theories to understand risk perception and behavioral formation of small-format mobility users. Specifically, this chapter focuses on the effectiveness and social impact of safety education on accident prevention and well-being promotion.

In regions like Southeast Asia, where motorcycles dominate urban transport, road traffic injuries remain a leading cause of mortality, exacerbated by inconsistent accident reporting and underdeveloped safety systems. This study underscores the importance of adopting comprehensive tools such as psychometrically informed models and culturally adaptive frameworks to evaluate risk perception and driving behaviors effectively.

By integrating cross-sector collaborative education programs, such as those successfully implemented in Vietnam, stakeholders can promote a sustainable motorcycle safety culture, fostering individual awareness and societal engagement. However, the lack of consistent training content in Thailand highlights the need for standardized evaluation methods and targeted interventions to mitigate habituated risky behaviors, including distracted or fatigued driving.

Furthermore, the economic and societal benefits of road safety interventions emphasize their critical role in achieving broader urban livability and sustainability goals. The rise of electric mobility solutions, including battery-powered two-wheelers, offers an opportunity to align environmental benefits with enhanced safety measures, creating a foundation for resilient and sustainable urban transport systems. By prioritizing well-designed safety initiatives and collaborative efforts, cities can not only reduce accident risks but also foster well-being, livability, and efficient mobility systems in motorcycle-reliant communities.

RQ3: How can behavioral changes towards more sustainable choices be promoted?

Promoting behavioral changes toward more sustainable mobility choices requires a multifaceted approach that addresses psychological, social, and practical factors influencing decision-making. ***Chapter 5*** examined a pilot project introducing community-based electric ride-sharing in Thailand, highlighting the pivotal role of travel-related self-efficacy in facilitating a shift from conventional travel modes to sustainable alternatives.

Trust emerged as a critical factor shaping perceived ease of use, attitudes, and social norms, acting as a control belief that either enables or hinders behavior adoption. The division of attitudes into instrumental and hedonic dimensions provided a nuanced understanding of consumer values, with both indirectly influencing behavioral intention through mediating variables such as eudaimonic value and self-efficacy. Eudaimonic value, reflecting a search for meaning and purpose in activities, was identified as a key driver of sustained behavioral change, reinforcing intentions to adopt community-based ride-sharing over private cars and taxis.

The findings further revealed differences between frequent and infrequent users of the service. For infrequent users, trust significantly influenced instrumental attitudes, underscoring the need for a reliable and trustworthy service to enhance perceived usefulness. Frequent users, on the other hand, were more motivated by normative values and exhibited higher self-efficacy, which was strongly correlated with sustained behavioral intention.

However, the study also found that intention declined when users were asked to pay for the service, highlighting the importance of affordability in sustaining behavioral change. By integrating the Theory of Planned Behavior with goal-framing theory, this research advanced theoretical frameworks for travel behavior interventions and emphasized self-efficacy as a critical mediator in connecting external influences to goal-striving processes. These findings provide practical insights for designing effective interventions that emphasize trust, user-centered design, and affordability to promote sustainable travel behavior and ensure long-term adoption.

RQ4: How can mobility technologies enhance well-being?

Chapter 6 investigates and models how personal values influence decision-making across varying service levels in different mobility options. The connection between people's virtue- and value-oriented happiness and their desired lifestyles in mobility choices is explored. Mobility technologies can enhance well-being by addressing both the practical and psychological dimensions of transportation.

First, they build trust and confidence among users by providing reliable, user-friendly, and efficient services, which positively influence instrumental, hedonic, and normative values. These values, in turn, contribute to eudaimonic well-being—derived from personal fulfillment and achievement—and interdependent well-being, which stems from shared social connections.

Second, mobility technologies cater to diverse user preferences by offering flexible and personalized options. For instance, electric vehicle ownership aligns with individual autonomy and environmental goals, enhancing eudaimonic well-being, while shared mobility services foster social connectivity, promoting interdependent well-being. Third, by reducing barriers to adoption, such as cost, reliability, and accessibility issues, mobility technologies can sustain user engagement and satisfaction. This ensures that users benefit from affordable, dependable, and value-aligned transport solutions. Over all, by aligning practical convenience with psychological satisfaction and sustainability, mobility technologies empower individuals to make transport choices that enhance their quality of life and promote a sense of purpose and connection within their communities.

7.2 Contributions

The original contributions of this thesis, aligned with the research questions, are as follows:

1. Conceptual Framework for Community-Centered Transport

A conceptual model defining and formulating community-centered transport and mobility development for resilient and self-sufficient cities is presented in Chapter 2. This chapter provides the foundational background for the entire thesis. The content is based on a published peer-reviewed journal article [7] (Chou, C. C. et al., 2021) and a peer-reviewed international conference paper [11] (Chou, C. C. et al., 2024).

2. Methodology for Assessing Spatial Cognition

A method to explore human cognitive maps by assessing travelers' spatial cognition in large-scale environments is described in Chapter 3. Using this proposed method, the study addresses RQ1. This chapter is based on a published peer-reviewed journal article [2] (Chou, C. C. et al., 2023).

3. Framework for Promoting Safety Culture

A cross-sector collaborative framework for promoting safety culture and its social impact is provided in Chapter 4. This framework serves as an important foundation for extended discussions in the thesis and address RQ2. The content is based on a published peer-reviewed journal article [6] (Chou, C. C. et al., 2022).

4. Theoretical Behavior Model for Motorcyclist Behavior Formation

A theoretical behavior model incorporating psychometrics and cultural theory to explain motorcyclist behavior formation is proposed in Chapter 4. This model help addresses RQ2. The content is being prepared for submission to a peer-reviewed journal.

5. Integrated Behavior Model for Sustained Behavior Change

An innovative integrated behavior model is proposed in Chapter 5 to explain decision-making in sustained behavior change toward sustainable travel modes. This chapter addresses RQ3 and is based on a published peer-reviewed SCI journal article [1] (Chou, C. C. et al., 2024).

6. Influence of Personal Values on Mobility Choice and Well-Being

A study investigating the influence of personal values on mobility choices and their impact on well-being is described in Chapter 6, addressing RQ4. This chapter is based on a peer-reviewed international conference paper [10] (Chou, C. C. et al., 2024).

7.3 Limitations and Future Works

This thesis contributes to advancing the understanding of mobility systems by exploring community-centered concepts. The findings indicate that enhancing users' spatial cognition, self-efficacy, positive emotions, and behavioral expansion significantly improves social acceptability. This is crucial for promoting the adoption of environmentally friendly mobility solutions that contribute to carbon neutrality and for shaping urban transportation policies that elevate individual values and well-being. Despite its significant contributions, there are some limitations that need to be addressed in future research.

1. Sample Size and Generalizability

One limitation is the small sample size in the pilot studies for small-format mobility (Chapter 3) and ride-sharing services (Chapter 5). While the rigorous mixed-method designs offer valuable insights, the limited sample size affects the generalizability of the findings. Future research should include larger, more diverse samples to improve robustness and applicability across varied populations and contexts.

2. Absence of a Control Group in Interventions

The pilot studies, as describe in Chapter 3, exploring the effect of spatial exploration on spatial cognition without a control group, it is challenging to fully isolate the effects of the intervention from external influences. Future studies should incorporate experimental designs with control groups to provide more conclusive evidence.

3. Cross-Cultural Adaptability

While this thesis employs psychometrics and cultural theories to study behavior formation in Southeast Asia, the cultural contexts are specific to Thailand. The findings may not be directly applicable to other regions without adaptation. Further research is needed to test the proposed models and frameworks in different cultural settings to validate their adaptability and scalability.

4. Limitations in Longitudinal Analysis

The reliance on survey data rather than panel data limits the ability to track changes in actual travel patterns over time, as discussed in Chapter 5. While this study utilized a long-term pilot service survey to gather insights, it primarily provides evidence of users' experiences and developmental changes at that time, rather than capturing continuous, real-time behavioral evolution.

Future Research Directions

Building on the findings of this thesis, future research will focus on developing a hybrid model that integrates machine learning with behavioral models grounded in psychometrics and econometrics. This approach aims to address limitations in current methodologies by leveraging the strengths of both machine learning and statistical modeling.

AI offers exceptional predictive accuracy but often functions as a black box, making the processes behind its predictions difficult to interpret. In contrast, statistical methods are effective in uncovering causal relationships but face challenges such as high data collection costs and vulnerability to biases. Combining these approaches will enable more accurate and transparent understanding of human behavior while enhancing AI's predictive capabilities.

This hybrid framework has significant potential in transport and urban planning. By integrating machine learning's predictive power with the causal insights of econometric models, future research can provide actionable insights for designing human-centered urban transport systems. Such an approach is particularly critical for developing technologies that not only address operational efficiency but also align with human values, well-being, and long-term sustainability goals.

List of Relevant Publications

Peer-Reviewed International Journal

[1] **Chou, C. C.**, Iamtrakul, P., Yoh, K., Miyata, M., & Doi, K. (2024). Determining the role of self-efficacy in sustained behavior change: An empirical study on intention to use community-based electric ride-sharing. Transportation Research Part A: Policy and Practice, 179, 103921.

[2] **Chou, C. C.**, Yoh, K., Hirokawa, S., & Doi, K. (2023). Co-evolution of Smart Small Vehicles and Human Spatial Experiences: Case Study on Battery-Sharing Electric Two-wheelers Experiment. Sustainability 2023, 15.

[3] Takano T., Morita H., Miyata M., **Chou C. C.**, Yoh K., & Doi K. (2023). Proof of Concept on District Mobility Service Using Small Electric Vehicles toward Realizing A Decarbonized City, Asian Transport Study 2023

[4] Yamachi S., **Chou C. C.**, Yoh K., Doi K., & Aoki Y. (2023). The Impact of Waiting and Resting Space Improvements at a Regional Railway Station on Users' Attitude and Behavior, EASTS Journal 2023

[5] Horiike, T., Yoh, K., Doi, K., & **Chou, C. C.** (2023). Assessing the Hierarchical Diversity of Public Transportation Considering Connectivity and Its Implication on Regional Sustainability. Sustainability, 15(23), 16494.

[6] **Chou, C. C.**, Yoh, K., Inoi, H., Yamaguchi, T., & Doi, K. (2022). Effectiveness evaluation on cross-sector collaborative education programs for traffic safety toward sustainable motorcycle culture in Vietnam. IATSS research, 46(2), 258-268

[7] **Chou, C. C.**, Aoki, Y., Yoh, K., & Doi, K. (2021). New local design in the new normal: Sustainable city for outbreak risk. IATSS research, 45(4), 395-404.

[8] Mwebesa, M. E., **Chou, C. C.**, Yoh, K., & Doi, K. (2021). A Cross-Sector Framework to Boost the Sustainable Implementation of Integrated Transport and Spatial Strategies to Improve Safety and Mobility of Moto-Taxi Riders. Frontiers in Sustainable Cities, 3, 775011.

[9] Nakase, R., **Chou, C. C.**, Aoki, Y., Yoh, K., & Doi, K. (2021). Evaluating Hierarchical Diversity and Sustainability of Public Transport: From Metropolis to a Weak Transport Demand Area in Western Japan. Frontiers in Sustainable Cities, 3, 667711.

Peer-Reviewed International Conference Paper

[10] **Chou, C. C.**, Yoh, K., Kii, M., & Doi, K. (2024). Owning or Sharing a Car: Analyzing the Role of Authenticity and Conformity in Mobility Decisions. Urban Transitions 2024, Sitges, Spain.

[11] **Chou, C. C.**, Doi, K., & Kii, M. (2024). Time Wealth as a Determinant of Public Transport Behavior: Empirical Evidence from Japan. 2024 International Conference and Annual Meeting of the Chinese Institute of Transportation, Taichung, Taiwan

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