DOCTORAL DISSERTATION

A comparative analysis of commuter's travel behaviors towards different types of ride-hailing services: The case of Hanoi, Vietnam.
(異なる配車サービスに対する通勤者の交通行動に関する比較分析：ベトナム、ハノイの事例)

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A thesis submitted to the Graduate School of Urban Innovation in partial fulfillment of the requirements for the degree of

Doctor of Philosophy in Engineering

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Abstract

This dissertation explores the diversity in commuter travel behaviors toward motorcycle-based and car-based ride-hailing services (MRHS and CRHS) in Hanoi, Vietnam. The research was motivated by the need to understand how different types of RHS influence user behavior in a developing urban environment. A review of current literature revealed that while the global impacts of RHS are well-documented, regional studies, especially in motorcycle-reliant societies, are sparse and inconclusive. Addressing this significant gap in the existing transportation research, this study illuminates the unique dynamics of RHS in Southeast Asia, where motorcycles are a prevalent mode of transport Using multinomial logit and bivariate probit regression analyses on data from 500 RHS users, the study identified that income levels and vehicle ownership significantly have contrasting effects on MRHS and CRHS usage. Notably, the use of MRHS is positively linked to its role as a feeder mode to metro stations, whereas CRHS usage shows a negative correlation. Additionally, the study highlights a user preference for MRHS over CRHS during peak traffic hours. Furthermore, the analysis highlighted that fare changes substantially impact MRHS usage, while CRHS usage is not significantly affected. The study faced challenges in fully capturing the effects of external factors, such as policy changes and technological advances, on RHS usage. Despite these challenges, the research contributes to urban transportation policy by emphasizing the necessity for distinct strategies for MRHS and CRHS. The findings suggest that integrating RHS with public transport systems should be tailored to leverage the specific advantages of each RHS type, fostering a more efficient urban mobility landscape.

Acknowledgements

I want to dedicate the very first words of this thesis to express my deepest gratitude to those who, without their guidance and support, would not have been able to complete my doctoral dissertation.

First and foremost, I would like to express my heartfelt gratitude to my supervisor, Prof. Dr. Shinji Tanaka, for their continuous support, brilliant insights, and valuable guidance throughout the process of my doctoral study and related research, for his patience, motivation, and immense knowledge. His comments and recommendations during research time led me to the right approach for the whole study.

I sincerely thank the respected members of the thesis committee, including Prof. Dr. Mihoko Matsuyuki (co-supervisor), Assoc. Prof. Dr. Abe Ryosuke (co-supervisor), Prof. Dr. Kikumoto Mamoru, and Assoc. Prof. Dr. Komatsu Satoshi. Your precious advice, expertise, thoughtful comments, and great feedback were not just helpful but integral to the success of my research work.

My sincere thanks also go to Assoc. Prof. Dr. Nguyen Hoang Tung of the University of Transport and Communications, Prof. Dr. Hironori Kato of the University of Tokyo, and Dr. Phan Le Binh of Oriental Consultants Global Co., Ltd, who encouraged me to start this journey and later continued to give me their kindly support and opinions, which played an essential role in shaping and concluding the research.

I am thankful to the Ministry of Education, Culture, Sports, Science and Technology (MEXT) and the Japan International Cooperation Agency (JICA) for providing the scholarship and the research allowance which were indispensable for conducting this research.

I extend my gratitude to people of the Graduate School of Urban Innovation, Yokohama National University. The academic environment you created was not just wonderful, but instrumental. To my fellow lab members, the knowledge and experiences we shared over the past three years will forever be cherished and remembered.

Finally, but by no means least, my special gratitude goes to my family: my parents, Mr. Tran The Phuong and Mrs. Nghiem Thi Phuong, for their unconditional love and encouragement; my brother, Tran Huy Hieu, for his moral backing; my dear wife, Tran Thi Minh Thuy, for her unbelievable care and assistance; my little darling daughter, Ms. Tran Ngoc Khanh An, and other friends in Vietnam and Japan. They are a great source of spiritual motivation and are indispensable in helping me complete this challenging journey.

Dedication

Dedicated to my beloved parents

Mr. Tran The Phuong *and* ***Mrs. Nghiem Thi Phuong***

my dear wife ***Tran Thi Minh Thuy*** *& adored daughter* ***Tran Ngoc Khanh An***

And

My siblings, teachers, and other family members for their unconditional love,

endless support and encouragement.

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List of Abbreviations

AIC	Akaike's Information Criterion
ASEAN	Association of Southeast Asian Nations
BP	Bivariate Probit Regression Model
BOP	Bivariate Ordered Probit Regression Model
CRHS	Car-based Ride-Hailing Services
MNL	Multinomial Logit Regression Model
MRHS	Motorcycle-based Ride-Hailing Services
RHS	Ride-Hailing Services
SEA	Southeast Asia
UMRT	Urban Mass Rapid Transit
VIF	Variance Inflation Factor

Chapter 1. Introduction

1.1. Research Background

The transformation of the urban transportation market during the last decade has undoubtedly been strongly influenced by RHS. RHS represents a form of mobility-on-demand in which travelers, instead of driving their own vehicles, pay for service trips through a smartphone application (Susan Shaheen et al., 2017). RHS connects consumers to drivers to provide transportation services based on short-term contracts. RHS offers the same services as traditional taxis but differs mainly in fare structures, operating rules, and service booking platforms (Hoang-Tung et al., 2022). Uber was founded in the US in 2009, paving the way for explosive growth for RHS as the first company to offer this service. As of 2016, RHS expanded significantly and became popular worldwide, with 171 countries using different application platforms. Uber is the world's most popular Ride-Hailing app, leading the market with 107 out of 171 countries, or 62% of the available territories, followed by Careem and Grab (Jonathan Marciano, 2016). As of 2023, companies offering RHS continue to thrive globally, with ongoing efforts to integrate more environmentally friendly vehicles, such as electric automobiles, into their operations.

Existing scientific contributions on RHS have explored the service's influence on various aspects. As Felipe F. Dias (2021) specified, there are four significant topics of discussion around RHS: disruption, travel demand, regulation, and automation. There are also three groups of stakeholders related to RHS and the transportation market defined, including demand-side (RHS users), supply-side (RHS companies and entities providing communications for connecting users and RHS providers), and public-sector stakeholders (transport planning agencies, transportation regulatory agencies, other related transportation operators, such as taxi companies and public transit agencies) (Chalermpong et al., 2022). However, most findings and contributions of existing articles and studies focus on US cities, while other regions of the world also experience substantial growth in Ride-hailing use (Gomez et al., 2021). Examining the existing research outcomes on RHS, numerous contradictory findings exist regarding the travel behaviors of RHS users to public transportation. These conflict results indicate the possibility of non-uniform impacts of RHS, which has yet to be explored or sufficiently addressed in academic research.

Notably, the diversity in RHS impacts is likely to be particularly pronounced in the context of Southeast Asian (SEA) countries. Such phenomenon is attributed to the distinct applications of RHS in SEA cities, which differ markedly from other regions globally. SEA cities not only feature the conventional four-wheeler RHS but also incorporate two-wheeler and three-wheeler RHS. These cities are characterized by unique transportation market attributes: a relatively underdeveloped public transport system, high population densities, and a significant reliance on private transportation, particularly motorcycles. The environmental and contextual variations in implementing RHS services are crucial in shaping the demand for RHS and influencing user behavior patterns. Despite the apparent importance of these factors, there is a notable absence of research focusing on the heterogeneity of user travel behaviors attributable to the diverse types of RHS in the SEA region. Therefore, it is necessary to elucidate and contrast the influences of different RHS types (MRHS and CRHS) on commuter travel behaviors and discuss their potential role in strategies to augment public transport system development. Such results could provide empirical evidence about the different types of RHS impacts in developing countries using the case of Hanoi, Vietnam. It contributes to the formulation of strategic policies for managing different RHS types. Such policies could encourage a gradual transition away from dependence on personal vehicles, thereby promoting more widespread adoption of public and shared transportation modalities in the future.

1.2. Problem Statement

Vietnam, a typical motorcycle-based society, is experiencing significant shifts in its urban transportation dynamics. The number of vehicles, particularly motorcycles, has seen exponential growth. For example, in Hanoi alone, motorbike registrations increased from 5.7 million in 2008 to 8.2 million in 2020. This surge has greatly burdened the road infrastructure, contributing to traffic congestion and environmental concerns. In response to these challenges, the Vietnamese government initiated the development of Urban Mass Rapid Transit (UMRT) systems starting in 2008, intending to reduce road congestion and provide efficient, sustainable public transport options. The plan included the construction of 14 metro lines in Hanoi, intending to shift the primary mode of commuting from motorcycles to public transport. However, progress has been slow and fraught with delays; for instance, the first urban railway line was only introduced in 2021 after more than a decade of construction, and full operation of more lines is still anticipated as far in the future as 2027.

During such circumstances, a new element entered Vietnam's transportation market, the RHS, which has further complicated this landscape. Uber and Grab entered Hanoi's transportation market, introducing RHS with both motorcycles and car-based options in 2014. These services quickly became a preferred mode of transport due to their convenience, competitive pricing, and the ability to meet the immediate mobility needs of the urban population. Although Uber exited in 2018 and transferred its operations to Grab, multiple local providers have since emerged. The explosive growth of RHS, particularly motorbike taxis, seems contradictory to the public transport-oriented policies. The lack of regulatory control over RHS activities has led to debates, especially since these services could undermine traffic reduction goals by encouraging motorbike use.

The competitive dynamics introduced by RHS have not only affected the market share of conventional taxis but also posed new questions about the role and effectiveness of the planned UMRT system. Thus, the question of the possible impacts of different types of RHS on Vietnam's traffic environment becomes practical and urgent.

1.3. Research Objectives and Questions

The primary objective of this study is to examine the heterogeneity in travel behaviors caused by the impact of different types of ride-hailing services (RHS), specifically motorcycle-based and car-based, on commuters and the public transportation system in Vietnam. Policy recommendations and strategies are suggested for optimizing RHS's operational efficiency with Hanoi's public transportation system development plan. The following research questions are addressed in this study.

- Is the socioeconomic status of motorcycle-based and car-based RHS users different?
- What is RHS's role in the Vietnam transportation market? Is this the same for motorcycle-based and car-based RHS?
- Are there any relationship between personal vehicle ownership (motorbike and car) and frequency of MRHS and CRHS use?
- People that use (different types) of RHS, are their commute behaviors the same or different in rush hours?
- What is the reaction of RHS (motorcycle and car-based) users when there is a change in usage price?

In order to achieve the research goal, the study is structured around sub-objectives related to the research questions. Regarding the role of RHS in Vietnam's transportation market, the focus is on evaluating the potential impacts of MRHS and CRHS on public transport as a feeder mode. This focus aligns with the goal of developing and integrating an effective public transport system in Vietnam. For the question concerning commuters' behaviors when using different types of RHS, the study examines behaviors prevalent in motorcycle-based societies: personal vehicle usage behavior and behavior during rush hour. The first and fourth questions directly become objectives. Therefore, the sub-objectives are stated as follows.

1. To study on how the socioeconomic of users related to the usage of different RHS types
2. To study on the potential influence of different RHS types on public transport
3. To study on how different types of RHS usage are affected by private vehicle ownership
4. To study on how commuters use different types of RHS during rush hour
5. To study on the effect of price changes on users of different types of RHS

The development of hypotheses based on these sub-objectives is further described in section 2.4

1.4. Significance of the study

This study's exploration of the differential impacts of motorcycle-based and car-based RHS in Hanoi provides crucial insights for urban transportation planning and policy development. By distinguishing between the effects of MRHS and CRHS on urban mobility, the research informs targeted policies and strategic planning aimed at improving transportation systems and reducing urban congestion. The findings help policymakers design effective regulations, such as RHS zoning laws and pricing strategies, and guide infrastructure investments, ensuring they align with current urban mobility trends and public needs. Furthermore, this research fills a significant gap in the academic literature by providing a detailed analysis of RHS in a motorcycle-prevalent society, an underrepresented topic in existing studies. The socioeconomic implications drawn from the study contribute to a broader understanding of how different income groups interact with RHS and the potential impacts, supporting efforts to enhance transportation equity and sustainability.

The study's implications extend beyond local policy applications, offering valuable insights for global urban centers experiencing similar transportation challenges. It highlights the importance of integrating innovative transportation models like RHS into traditional transit systems to create more resilient, efficient, and inclusive urban environments. Additionally, the findings significantly contribute to academic discourse by providing a new perspective on the role of RHS in shaping travel behaviors in motorcycle-based societies. Southeast Asian countries, where cities share similar characteristics in terms of vehicle types, the development level of urban public transport, and the types of RHS that can be utilized, will find the results of this study particularly applicable. Such understanding could be essential for researchers studying urban mobility in these countries in particular and developing countries in general. Furthermore, this research not only advances theoretical frameworks but also provides actionable data that could significantly influence future transportation strategies, promoting a shift towards more sustainable and equitable urban mobility solutions.

1.5. Scope and limitations

This research specifically addresses the impact of MRHS and CRHS on urban mobility in Hanoi, Vietnam. It utilizes a comprehensive dataset of 500 RHS users, gathered through local interviews, to analyze and compare how different types of ride-hailing services influence travel behavior. The focus is primarily on evaluating the socioeconomic factors affecting usage patterns, the role of RHS in complementing or substituting public transportation, and the interaction between RHS and personal vehicle ownership. The research methods include multinomial logit and bivariate probit regression analyses, which provide a detailed understanding of user preferences and behaviors towards MRHS and CRHS during various conditions, such as peak traffic hours.

This study has several limitations that should be acknowledged. First, the data collected reflects user behaviors and preferences at a specific point in time and may not account for long-term trends or shifts in transportation dynamics due to technological advancements or policy changes. The static nature of the data limits the ability to observe how perceptions and usage of RHS might evolve as the urban infrastructure and regulatory landscape in Hanoi continues to develop. Additionally, the study focuses exclusively on Hanoi and may only partially represent the varied impacts of RHS in other urban settings, particularly those with different urban planning and transportation frameworks. Another limitation arises from the potential response bias in the survey data, as the sample is confined to individuals who agreed to participate and may not include a broader range of RHS users. Finally, the study does not extensively explore external influences such as economic fluctuations, environmental factors, or cultural attitudes that could significantly affect RHS usage and preferences.

1.6. Organization of the Thesis

This thesis is organized into seven chapters.

Chapter 1 sets the stage for the research by outlining the study's background, presenting the problem statement, and defining the research objectives and questions. It also discusses the significance of the study, delineates its scope and limitations, and describes the overall organization of the thesis.

Chapter 2 reviews existing literature on RHS, with a particular focus on studies from both developed countries and those specific to the SEA context. This emphasis on the regional relevance of the research synthesizes the findings from these studies to form a solid foundation for developing the hypotheses that guide the empirical investigation, underlining the importance of the study to the academic community in this region.

Chapter 3 details the research framework employed in the study, specifying the data needs and describing the various analytical methods used, including the Bivariate Probit Regression Model (BP), Bivariate Ordered Probit Regression Model (BOP), and Multinomial Logit Regression Model (MLN). This chapter also explains the differences between Logit and Probit models and outlines the expected outputs from these analyses.

Chapter 4 provides a comprehensive introduction to the study area, discussing the local context of Hanoi's transportation market, the emergence and development of RHS in Vietnam, and the specific areas surveyed. It also covers the methodologies for data collection and the nature of the datasets gathered, assuring the audience of the thoroughness of the study.

Chapter 5 presents an analysis of the socio-demographic profiles of the respondents, descriptive statistics, and a preliminary analysis of each hypothesis, providing initial insights into the factors affecting RHS preferences.

Chapter 6 presents detailed analysis results for each hypothesis and discusses these in the context of the existing literature and the study's theoretical framework. It integrates the findings from empirical analyses with broader discussions on the implications of these results.

Chapter 7 encapsulates the key conclusions drawn from the research and offers practical recommendations based on the findings. It also candidly discusses the study's limitations and suggests promising directions for future research.

Chapter 2. Literature Review

2.1. Studies about RHS effects in developed countries

Numerous studies on the impact of RHS on commuter travel behavior and transport mobility have been conducted in the US and Western countries, which are car-based societies. With the fact that RHS offers the same services as traditional taxis, most studies examining the nexus between them have demonstrated and confirmed the same substitution effect (Contreras & Paz, 2018; Nie, 2017; Zhong et al., 2021).

However, previous studies in these regions stated contradictory results regarding the impact of RHS on public transport. Ennen and Heilker (2020) from Germany claimed that RHS led to a strong substitution of public transport, cycling, and walking due to significantly lower fares. Two authors from Brazil, De Souza Silva et al. (2018) and Haddad et al. (2019), reported the same trend of RHS taking away passengers from public transit. This trend is generalized across many studies about RHS in US cities (Rayle et al., 2016; Clewlow et al., 2017; Henao et al., 2017; Monahan & Caroline, 2022). Noticeably, Hall et al. (2018) stated that Uber increases public transport use for the average transit agency, representing findings that are opposed to those of other studies, and this effect grows over time. Furthermore, other researchers in the US, Sadowsky & Nelson (2017), also indicated that Uber served as a complement to public transportation use. However, when Lyft, the second major RHS company, entered, the joint presence of the two major RH companies transformed RHS from a public transportation complement to a public transportation substitute. This substitution effect is also stated to be strengthened over time.

In addition, some authors, such as Young & Farber (2019) from Canada, specified that RHS is clearly insignificant and inconsequential in influencing the ridership level of other more substantial modes of travel, such as public transit and cars. Lee et al. (2022), also from Canada, found that their entry into a market increases traffic congestion and reduces public transit demand, particularly in cities with higher levels of urban compactness. A recent study in China found that the introduction of RHS to China's small- and medium-sized cities significantly increases public transit usage (Zhong et al., 2024). These authors also stated that the positive impact of RHS on public transit is proactive for about a year before weakening over time and then diminishes as time progresses. As indicated above, research findings on the impact of RHS in developed countries exhibit considerable variations between different nations and even within the same nation.

Moreover, there is a significant lack of research exploring the causes of these varying outcomes. Lavieri and Bhat (2019) suggested that these differences could be attributed to the varying impacts of RHS in cities with abundant public transit options and those with higher levels of car dominance. This divergence may also stem from the increasing number of companies entering the market, intensifying competition for customer acquisition. Additionally, these authors stated that as RHS becomes more accessible to a broader segment of the population, there is a likelihood that the general profile of RHS users, along with their trip characteristics, may exhibit significant deviations from current observations. The disparate effects of RHS on public transportation systems further suggest a potential heterogeneity in traveler behaviors influenced by RHS. Researcher Felipe F. Dias (2021) appears to notice this problem and share the viewpoint, mentioning that RHS can exhibit both complementary and substitutive effects on public transit. However, the dominance of one effect over the other varies on a case-by-case basis.

Noticeably, as one of the first studies tried to examine the heterogeneous impact of RHS on public transit use, Babar and Gordon (2020) pointed out that RHS has led to significant reductions in the utilization of city bus services but increased the utilization of commuter rail services. However, according to their study, this effect mainly depends on external factors such as local population size, violent crime rates, weather, gas prices, the quality of public transit options and only one factor related to user characteristics: transit riders' average trip distance. It should be noted that this study explored the effects of RHS in cities in the United States where only CRHS is available. With a similar attempt in Chinese cities with the research subject being MRHS only, Shi et al. (2021) also concluded that RHS reduces bus ridership but increases rail transit ridership. Furthermore, these authors stated that the effects refer to the shift of passengers from buses to rail transit due to the emergence of RHS.

The varied impacts of RHS on public transportation systems also indicate a potential heterogeneity in traveler behavior influenced by RHS. It is reasonable to expect that customer heterogeneity accounts for the contrasting results regarding the effects of RHS on increasing or decreasing public transport usage. To date, no studies have specifically examined this vital aspect of heterogeneity in traveler behavior.

2.2. Studies about RHS effects in Southeast Asian (SEA) countries

It is also worth noting that most existing research has focused on car-based societies, with few studies examining motorcycle-based societies. Car-based societies are markedly different from the developing countries of SEA, where motorcycles play a distinct role. RHS have evolved uniquely in this context to include a wider variety of vehicle types. This heterogeneity in RHS types could result in a broader spectrum of effects compared with other regions.

Even though RHS has been presented in the SEA region for quite a long time, the number of studies on it is still limited. Reviewing existing articles, although the results on the characteristics of RHS users have many similarities, the characteristics of RHS trips and customer behavioral intentions from these studies are quite diverse and somewhat challenging to synthesize (Chalermpong et al., 2022). With relatively few studies, contrasting results regarding the impact of RHS on travelers' behavior towards public transportation are also reported here. For example, a study on MRHS in Jakarta, Indonesia, posited that MRHS is a substitute for short distance public transport, especially minibuses (Suatmadi et al., 2019). On the contrary, M. Irawan et al. (2020) found that MRHS complemented conventional public transport as they served mainly access trips for TransJakarta bus and Jakarta commuter train. Such contradictory findings are also shown through studies on

CRHS in the region: complement effect in Singapore by (Su & Wang, 2019) and substitution effect in the Philippines by (Paronda et al., 2017).

Notably, there is a significant gap in the literature when it comes to comparative analyses between different RHS modes, such as cars and motorcycles. Existing research tends to focus solely on CRHS or MRHS, without comparing the two. One of the initial investigations into the distinctions between MRHS and CRHS revealed that commuters categorize private motorcycles and MRHS within the same subgroup of alternatives, while they consider private cars, CRHS independently (Hoang-Tung et al., 2022). Such insight provides a foundational understanding that customer heterogeneity could potentially explain the observed contradictory outcomes regarding the impact of RHS on public transportation systems, a crucial aspect for transportation planners and policymakers to consider.

Therefore, to address this research gap, this study aims to examine the heterogeneity in user travel behaviors in the context of MRHS and CRHS, using Hanoi, Vietnam, as a case study.

2.3. The significance to compare MRHS and CRHS

Through the literature review, it becomes evident that the presence of multiple types of RHS is a distinctive characteristic of Southeast Asia, with the most notable examples being MRHS and CRHS. This constitutes a critical distinction from Western societies, where research outcomes on the impacts of RHS also exhibit discrepancies. Furthermore, screening existing studies reveals that only some, if any, have concurrently investigated the impacts of

CRHS and MRHS in a separate and comparative manner. Typically, these services are often studied individually in separate research papers or under the general term of RHS. This constitutes a significant oversight, as the potential differences in user behavior between these two forms are likely attributable to the differing characteristics of the vehicles, as follows.

- MRHS is cheaper than CRHS with the same travel distance, making it more accessible to a broader range of the population, especially in lower-income brackets. This could also allow users to use the services more frequently compared with CRHS. CRHS is more expensive but offers a higher level of comfort, privacy, and safety, appealing to commuters who prioritize these factors over cost.
- MRHS, designed to carry only one passenger, are more suitable for short to moderate personal trips, providing a sense of exclusivity and convenience. In contrast, CRHS, with its higher carrying capacity of up to 4 or 7 passengers, is ideal for group travel, long-distance trips, or goods carrying trips.
- MRHS, utilizing motorcycles that generally occupy less space on the road, can navigate through congested traffic more efficiently. This results in shorter waiting and travel times, especially during rush hour. For commuters in a hurry or those needing to navigate through heavy traffic, MRHS could be a time-efficient choice.
- Moreover, MRHS would be a better door-to-door service for pick-up or drop-off in narrow areas such as lanes and alleys. CRHS could only pick up at a relatively extensive road.

As can be seen, the characteristics of MRHS and CRHS are significantly different. It is reasonable to consider that commuters utilize these services differently. The very first study about MRSH versus CRHS provided potential clues for such thinking by confirming that users consider MRHS to be the same alternative as their motorcycle. However, CRHS is not the same as their own car. This finding further insists on the importance and significance of comparing and understanding more about MRHS and CRHS, which is very necessary for those motorcycle-based societies standing on the threshold of the transition to cars.

2.4. Hypotheses formation.

Numerous researchers have confirmed that socio-economic factors are anticipated to significantly impact mode selection (S & Ramasamy, 2021). Therefore, it is reasonable to assume that all hypotheses should be based on the typical characteristics and perspectives of local commuters. Additionally, the advent of RHS has facilitated the ability of passengers to conveniently access and compare various modes of transportation, enabling them to make informed decisions regarding the most suitable mode of travel based on the specific requirements of each individual trip. The assumptions regarding the divergent influences of MRHS and CRHS are formulated based on the fundamental and readily observable differences between these two models: usage costs, accessibility, transportation capacity, and ease of maneuverability within traffic flow. With the principal aim of examining the differences between MRHS and CRHS, this study explored five aspects, upon which five corresponding hypotheses are formulated.

First, regarding the sociodemographic factors influencing the adoption of CRHS, existing studies conducted in Asia have identified that the majority of CRHS users tend to be young (Nistal, 2016.; Weng et al., 2017; Nguyen-Phuoc et al., 2020; M. Z. Irawan et al., 2022; Thaithatkul et al., 2023b) and female users (Weng et al., 2017; Thaithatkul et al., 2023a). Although research on MRHS is relatively limited, it has similarly observed comparable trends in user characteristics (Silalahi et al., 2017; Suatmadi et al., 2019; Thaithatkul et al., 2023a). Individuals with higher levels of education were reported to be more likely to adopt both modes of RHS (Rizki et al., 2021). However, it is essential to highlight that for an equivalent travel distance, the utilization of CRHS results in much higher costs in comparison to MRHS. Hence, it is justifiable to examine the distinction between MRHS and CRHS in relation to individual income. The first hypothesis is stated as follows.

H1. The utilization of MRHS and CRHS is influenced differently by varying income levels.

Second, one of the most pertinent questions in studies concerning RHS is its impact on existing modes of transportation. Although Western researchers share a common conclusion on the substitutive impact between CRHS and traditional taxis, their findings are inconsistent regarding the effect of CRHS on public transport, as shown in the literature review. Felipe F. Dias (2021) suggested that Ride-hailing can have both complementary and substitutive effects on transit. However, the dominance of one effect over the other seems to vary on a case-by-case basis. This proposition appears increasingly relevant in the context of SEA countries, where the varieties of RHS are more diverse.

Considering the fundamental differences between MRHS and CRHS, such as the capability to maneuver through congested traffic and narrow roads, being typically used for short travel distances (M. Irawan et al., 2020), having limitation to single-passenger conveyance, and being cost-effective, it would be judicious to hypothesize that MRHS may hold greater potential for facilitating connections to public transportation as compared to CRHS. Therefore, we formulate the following hypothesis:

H2. MRHS has the potential to serve as the first and last mile option for access trips to public transport. Meanwhile CRHS has the opposite effect.

Third, Hanoi, characterized by a significant reliance on motorcycles with over 70% of the modal share, demonstrates a substantial rate of personal vehicle ownership, influencing the limited utilization of public transport. To gradually encourage residents to shift towards public transport, in addition to developing metro lines, consideration should also be given to reducing personal vehicle ownership. Consequently, the relationship between RHS usage and personal vehicle ownership should also be considered. According to Nugroho et al. (2020), owning a private vehicle reduces the probability of choosing an online taxi system. However, it is also reported that the number of cars in a household positively affects an individual's CRHS adoption (Hoang-Tung et al., 2022). There appears to be another differential impact between MRHS and CRHS possibly. Thus, the third hypothesis is formulated as follows.

H3. Owning a motorcycle decreases the likelihood of using MRHS, while owning a car increases the likelihood of using CRHS.

Fourth, commuters are likely to favor MRHS over CRHS during peak hours. MRHS possesses an advantage in conditions of traffic congestion as motorcycles can navigate around cars and through narrow lanes or alleys. Consequently, MRHS typically affords shorter waiting times, expedited travel, and more convenient passenger pick-up and drop-off under congested traffic conditions. A related claim has been validated, indicating that traffic congestion affects the choice of CRHS alternatives but not MRHS (Hoang-Tung et al., 2022). This phenomenon can be interpreted to suggest that MRHS users tend to remain consistent in their choices during traffic congestion, while CRHS users may be inclined to alternative options. We aim to validate this interpretation in our study's context of waiting time. Accordingly, we propose our fourth hypothesis as follows.

H4. During rush hours, commuters prefer to ride MRHS over CRHS due to shorter waiting time.

Finally, dynamic pricing is one of the most unique features of RHS. It is possible by using algorithms to optimize the price before showing it to users through their application. The dynamic pricing optimization is proven to be quite effective in increasing operator revenues, decreasing relocation costs, and reducing average wait times for passengers (Iacobucci & Schmöcker, 2021). Furthermore, RHS providers use these algorithms to make themselves more competitive in the market. Sun et al. (2019) found that the platform price is below the regular taxi fare in certain conditions, especially when traffic conditions are good. Traditional taxis and RHS are indeed identified as competitors. When mentioning the competition between RHS providers, as they all try to optimize their price based on their own formula, the gap between them could not be so much. Therefore, more prominent companies with financial resources carry out promotion campaigns or coupon redemption to lower the price even more and increase user satisfaction, aiming to dominate the market. Some researchers have noticed such promotions in their studies (Adam et al., 2020.; Nguyen-Phuoc et al., 2020; Munandar & Munthe, 2019). However, due to financial problems and increasing operating costs, such campaigns are becoming less frequent, and service prices have and will likely increase. This will almost certainly affect users, and with logical thinking, MRHS users will be more affected because they are more sensitive to financial changes. Thus, the fifth hypothesis is stated as follows.

H5. MRHS users are more susceptible to the impact of fare increases than CRHS users.

Chapter 3. Methodology

3.1. Research framework

Figure 3-1 illustrates the research matrix in order to determine the next actions and parameters necessary for the validation of the proposed hypotheses and ensure the connections to achieve the main goal.

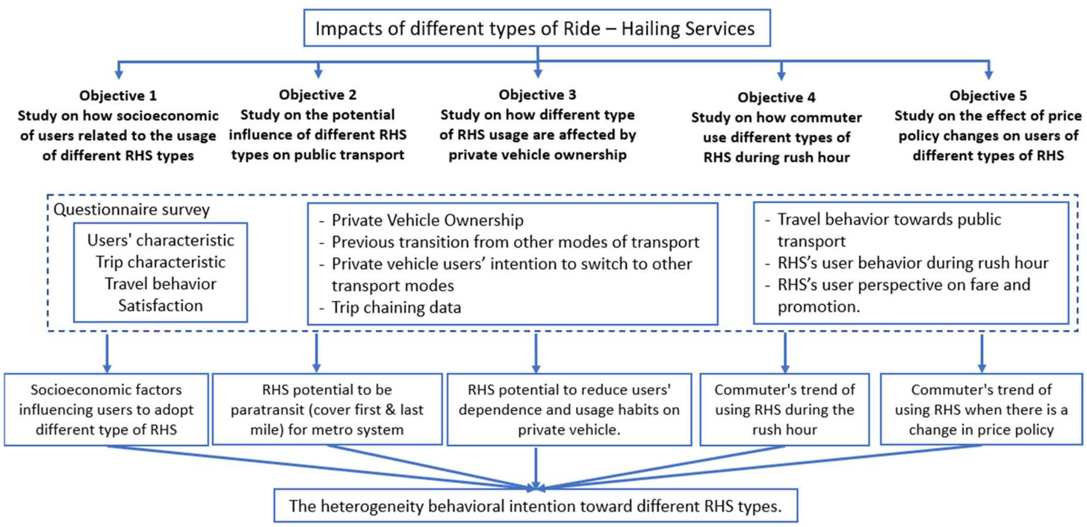

Figure 3-1 Research Framework

The research framework for this study is designed to explore the impacts of different types of RHS on urban mobility. This framework comprises several interconnected components: users' characteristics, trip characteristics, travel behavior, and satisfaction levels. These elements help examine how personal and trip-related attributes influence the preference and utilization of RHS. Additionally, the framework incorporates an analysis of socioeconomic factors, RHS's potential roles as paratransit, and its influence on private vehicle use. It looks into RHS's capability to integrate with the metro system, specifically as a first and last-mile solution, and assesses whether RHS can alter habitual reliance on private vehicles. Another crucial aspect of this framework is understanding commuter trends, particularly during peak hours and in response to fare changes, which will help in assessing the sustainability and behavioral adaptability towards RHS. This comprehensive approach allows for a detailed exploration of how RHS impacts urban transport dynamics and user behavior in the context of Hanoi's evolving transportation landscape.

3.2. Data needs

To address the research questions outlined in the framework, the study requires diverse data spanning users' demographic profiles, travel patterns, and RHS usage specifics. This includes:

- **Users' Characteristics**: Age, income, employment status, and frequency of RHS use.
- **Trip Characteristics**: Trip frequency, duration, purpose, and usual mode of transport before adopting RHS.
- **Travel Behavior and Satisfaction**: Changes in travel behavior since adopting RHS, satisfaction levels with RHS compared to other modes of transport, and detailed feedback on service attributes like cost, convenience, and safety.
- **Socioeconomic and Vehicle Usage Data**: Data on vehicle ownership, previous modes of transport, and intention to switch transport modes. This will aid in understanding the impact of socioeconomic factors on the choice of RHS.

- **RHS Usage Patterns**: Data on how commuters use RHS during rush hours, their responses to fare changes, and overall trends in RHS usage over time.

Collecting this data will involve conducting surveys and interviews with RHS users, alongside gathering secondary data from transport agencies and RHS providers.

3.3. Analysis Method

3.3.1. Bivariate Probit Regression Model (BP)

For H1 and H2, the expected input data as dependent variables are the usage of MRHS and CRHS, indicating whether respondents use MRHS and/or CRHS. Bivariate probit models are chosen for their ability to jointly model two binary outcomes. The BP enables empirical analysis of two distinct latent binary processes that jointly produce a single observed binary outcome. Utilizing this approach allows for a deeper understanding of the interrelationship between the two outcomes. This model has been widely used in transportation research to explore and understand various aspects of travel behavior (Mokhtarian & Cao, 2008; Le-Klähn et al., 2015; Fountas et al., 2019), including RHS research (Dias et al., 2017; Thaithatkul et al., 2023a). The BP is expressed in the Equation (1):

$$\begin{cases} Y_{i,k_1} = \beta_{k_1} X_{i,k_1} + \varepsilon_{i,k_1} \\ Y_{i,k_2} = \beta_{k_2} X_{i,k_2} + \varepsilon_{i,k_2} \end{cases} \quad (1)$$

The outcomes are specified as:

y_{i,k_1}= 1 if Y_{i,k_1}> 0 and y_{i,k_1}= 0 otherwise

y_{i,k_2}= 1 if Y_{i,k_2}> 0 and y_{i,k_2}= 0 otherwise

Where: **Y** illustrates a dependent variable,

X illustrates a vector of independent variables,

$\boldsymbol{\beta}$ illustrates a vector of coefficients associated with those variables,

$\boldsymbol{\varepsilon}$ is a standard normally distributed random error term,

$\boldsymbol{y}$ is a binary outcome,

subscript $\boldsymbol{i}$ illustrates an individual,

subscript $\boldsymbol{k_1}$ and $\boldsymbol{k_2}$ illustrate the two variables represent choices, MRHS and CRHS

The marginal effects for the joint probability when respondents choose "Both RHS types" are available when both y_{i,k_1} and y_{i,k_2}= 1.

The error terms ε_{i,k_1} and ε_{i,k_2} associated with BPM are posited to be correlated with correlation ρ.

$$\begin{pmatrix} \varepsilon_{i,k_1} \\ \varepsilon_{i,k_2} \end{pmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \rho \\ \rho & 1 \end{pmatrix}\right)$$

If the correlation turns out insignificant, then it could be estimated with two separate probit models, otherwise a bivariate probit model has to be used. In the other words, significant of correlation ρ indicates the reasonableness and correctness of using BPM method in the case.

3.3.2. Bivariate Ordered Probit Regression Model (BOP)

For H3, the expected dependent variable is the frequency of using MRHS and CRHS, which indicates how often respondent use MRHS and/or CRHS (times/week). The Bivariate Ordered Probit model (BOPM) should be used, as these variables are ordinal. The model closely resembles the Bivariate Probit model (BP) but differs when specifying the outcomes, as the variables are now ordinal rather than binary. The BOP is expressed in Equation (2):

$$\begin{cases} Y_{i,k_1}^{*} = \beta_{k_1}^{*} X_{i,k_1}^{*} + \varepsilon_{i,k_1}^{*} \\ Y_{i,k_2}^{*} = \beta_{k_2}^{*} X_{i,k_2}^{*} + \varepsilon_{i,k_2}^{*} \end{cases} \quad (2)$$

The outcomes are specified as:

$$y_{i,k_1}^{*} = \text{j if } \mu_{k_1,j} < Y_{i,k_1}^{*} \leq \mu_{k_1,j+1}$$

$$y_{i,k_2}^{*} = \text{j if } \mu_{k_2,j} < Y_{i,k_2}^{*} \leq \mu_{k_2,j+1}$$

Where: **Y** illustrates a dependent variable,

$\boldsymbol{\mu}$: the threshold to specify **Y**

X illustrates a vector of independent variables,

$\boldsymbol{\beta}$ illustrates a vector of coefficients associated with those variables,

$\boldsymbol{\varepsilon}$ is a standard normally distributed random error term,

$\boldsymbol{y}$ is a binary outcome,

subscript $\boldsymbol{i}$ illustrates an individual, subscript $\boldsymbol{k_1}$ and $\boldsymbol{k_2}$ illustrate the two variables represent choices, MRHS and CRHS

The error terms ε_{i,k_1} and ε_{i,k_2} associated with BOPM are also posited to be correlated with correlation ρ.

$$\begin{pmatrix}\varepsilon_{i,k_1}\\ \varepsilon_{i,k_2}\end{pmatrix} \sim N\left(\begin{pmatrix}0\\0\end{pmatrix}, \begin{pmatrix}1 & \rho\\ \rho & 1\end{pmatrix}\right)$$

If the correlation turns out significantly, the choice of using BOPM and the results of the analysis would be considered more reliable.

3.3.3. Multinomial Logit Regression Model (MLN)

MNL is used for analyzing H4 as the respondent choice is expected to between independent options. The MNL is a popular choice in utility function techniques used for modeling and identifying mode choices in travel behavior analysis. It statistically links each traveler's decision to the characteristics of the available alternatives. The MNL model assumes that all alternatives in the choice set adhere to the property of independence from irrelevant alternatives, treating each option equally (Al-Salih & Esztergár-Kiss, 2021). It calculates the choice probabilities for each alternative as a function of the systematic portion of the utility of all the alternatives. The formula for Multinomial Logit Regression is formed as follow:

Y_{ij} = 1, if individual i select alternative j (j = 1,2, …, n,).

Y_{ij} = 0, for others alternative rather than j (non-selected alternatives)

$$\pi_{ij} = Pr(Y_{ij} = 1)$$

Where Pr is the probability of alternatives chosen.

$\pi_{i1}, \pi_{i2}, \ldots, \pi_{in}$ is illustrated the probability of individual i select alternative 1,2,…n .

The sum of mutually exclusive and complete event probabilities must be 1. These are called response probabilities.

$$\Pr(Y_{ij} = 1) + \Pr(Y_{ij} = 0) = 1$$

Respondents have to choose between the given alternatives, then obviously:

$$\pi_{i1} + \pi_{i2} + \ldots + \pi_{in} = 1$$

This means that in our example if we define any n-1 probabilities, then the final one is determined automatically. In other words, we cannot estimate these probabilities independently.

The Multinomial Logit Model formula:

The probability of selecting an alternative 'k' from a choice set of j alternatives is expressed using Equation (3):

$$\Pr(i,k) = \frac{\exp(V_{i,k})}{\sum_{k}^{j} \exp(V_{i,k})} \quad (3)$$

Where: $Pr(i,k)$ is the probability of individual i choosing alternative k;

$V_{i,k}$ is the utility function for alternative k by individual i;

j is the choice set of alternatives.

The General Multinomial Logit Regression (MNL) formula:

$$\log\left(\frac{\pi_j}{\pi_k}\right) = \alpha_{jk} + \beta_{jk}X_1 + \beta_{ik}X_2 + \ldots + \varepsilon_{ij} \quad (4)$$

The logits are linear functions of the explanatory variables and are the logs of the odds ratios. So, the odds ratio tells us how much option j is preferred over option k.

One alternative would be selected as base category also known as reference category or comparison category and assign its coefficient values to 0. Therefore, with n alternatives we will have (n-1) sets of regression results.

3.3.4. Different between Logit and Probit

The probit and logit models are both used extensively in statistical analysis to model binary outcomes, employing different link functions to map predicted values to probabilities. The probit model utilizes the cumulative distribution function of the standard normal distribution. It assumes that the underlying latent variable associated with the binary outcome is influenced by predictors through a linear combination, with error terms that are normally distributed. In contrast, the logit model employs the logistic function, which is the cumulative distribution function of the logistic distribution. This model also involves a latent variable influenced by predictors, but here the error terms are assumed to follow a logistic distribution, leading to different tail behaviors in the predicted probabilities.

Mathematically, the probit link function is represented by $\Phi(X\beta)$, where Φ is the CDF of the normal distribution, while the logit link function is expressed as $\Lambda(X\beta) = e^{(X\beta)} / (1 + e^{(X\beta)})$. This fundamental difference in link functions results in distinct interpretations of model coefficients. In probit models, the coefficients indicate how a unit change in predictors alters the probability of the outcome in terms of the standard deviation of the underlying normal distribution. In logit models, coefficients reflect changes in the log odds of the outcome, making them intuitively easier to understand in terms of odds ratios, especially in fields like medicine and public health.

Another critical distinction lies in the behavior of the tails of the distribution functions used. Logit models exhibit heavier tails than probit models, implying that they are more sensitive to outliers or extreme values. This is because the logistic distribution declines more slowly than the normal distribution. On the other hand, the probit model, with its lighter tails, might be more robust to the presence of outliers due to the properties of the normal distribution.

From a computational standpoint, logit models tend to be simpler and faster to estimate than probit models. The logistic function's mathematical properties lend themselves to easier computational handling, particularly when using methods like maximum likelihood estimation. Probit models, however, require numerical integration to compute the normal CDF, which can be computationally more demanding.

The choice between using a probit or logit model typically depends on the specific context of the research and assumptions about the distribution of the error terms. While both models generally provide similar results when the outcome variable is not rare, their estimates might diverge under different assumptions about the error distribution. Researchers often choose based on computational convenience, the tradition in their specific field, or the interpretability of the model outputs. It is also common practice to estimate both models to check the robustness of the findings, ensuring that conclusions are not overly dependent on the choice of model.

Specifically for this study, in H1, H2 and H3, the choice set of respondents are MRHS; CHRS and Both of MRHS & CRHS. As can be seen, the error component in the utility function of option “MRHS” or “CRHS” should be highly correlated with that of option “MRHS & CRHS”. Therefore, logit model becomes is not applicable because it assumes that the error components are identically and independently distributed. This is because logit models assume that the error term follows a logistic distribution. On the other hand, probit models assume that the error term follows a normal distribution which allows the bivariate models estimates decisions that are interrelated rather than independent. Thus, the probit approach is used for the bivariate model of H1, H2 and H3.

As for H4 and H5, the choice set of respondents are designed to be between distinctive options. As a result, Multinomial Logit model becomes suitable for application. The main reason for selecting logit over probit model in this case is because Multinomial Probit model is much complicated to use and also not necessarily for the study.

3.4. Expected outputs

The expected outcomes of this study are to:

- **Clarify the Role of RHS**: Determine the extent to which RHS are used as paratransit and their effectiveness in reducing private vehicle dependency.

- **Behavioral Insights**: Provide insights into commuter behavior changes in response to RHS, especially during rush hours and under varying economic conditions (e.g., fare changes).

- **Policy Implications**: Offer evidence-based recommendations for urban transport policy, particularly concerning the integration of RHS with existing public transport systems to enhance urban mobility.

- **Sustainability Assessment**: Evaluate whether RHS can be considered sustainable transportation modes based on user trends and behaviors.

- **Academic Contributions**: Contribute new knowledge to the field of transport studies, particularly in the context of developing countries where RHS has rapidly transformed the urban transportation landscape.

Chapter 4. The study area

4.1. Introduction

Hanoi, the capital of Vietnam, is a city of large scale and diversity in many aspects. As of 2023, Hanoi's population is approximately 8.5 million, making it one of the two most populous cities in the country. The city's area, following the administrative boundary expansion in 2008, covers 3,358.6 square kilometers, making Hanoi one of the largest cities in Vietnam by area. Economically, Hanoi's GDP in 2022 reached approximately VND 1,135 trillion (equivalent to USD 49.6 billion), with a per capita GDP of about USD 5,900, reflecting its position as the second strongest economy after Ho Chi Minh City. These characteristics underscore Hanoi's status as an important center of politics, economy, and culture in Vietnam. Administratively, Hanoi is divided into 12 districts, 17 rural districts, and 1 town, with 579 administrative units at the commune level, including wards, communes, and townships.

Due to rapid urbanization, Hanoi is experiencing significant growth in an often-unplanned manner, with increasing motorization rates. This chapter focuses on the context of Vietnam and Hanoi specifically. It provides an overview of the motorization trends in Hanoi. Additionally, this chapter offers valuable insights into the current development of the UMRT system in Hanoi. Following that, the process of emergence and development of RHS will also be mentioned in detail. The selection of the case study, which examines the interaction between ride-hailing services and commuter travel behavior in Hanoi, is also briefly described.

4.2. Local contexts of Hanoi's transportation market

Vietnam, a representative of the SEA region, is grappling with high population growth, especially in major cities like Hanoi. The population rose from 6.4 million in 2009 to 8 million in 2019, a 2.2% annual increase. This surge is paralleled by escalating traffic demands, evidenced by a substantial rise in vehicle registrations. By 2020, Hanoi hosted 7.6 million vehicles, including 740,000 cars and 5.8 million motorbikes, growing annually by 12.9% and 7.6%, respectively. This growth, partly due to increasing incomes, highlights a shift from motorcycles to cars (Ngoc et al., 2022). This surge in vehicle numbers not only exacerbates traffic congestion but also poses broader challenges for urban planning and environmental sustainability.

Vietnam is also a typical motorcycle-based society, a fact that significantly influences the urban transportation dynamics in Hanoi. According to the 2016 transportation mode share data (Figure 4-1), motorcycles overwhelmingly dominate Hanoi’s transportation landscape, accounting for 64.4% of the modal share. This preference for motorcycles is complemented by much smaller percentages for other modes of transport, including cars, buses, and the emerging urban railway, underscoring the challenges of diversifying transportation options in a city where motorcycles are deeply embedded in the commuting culture.

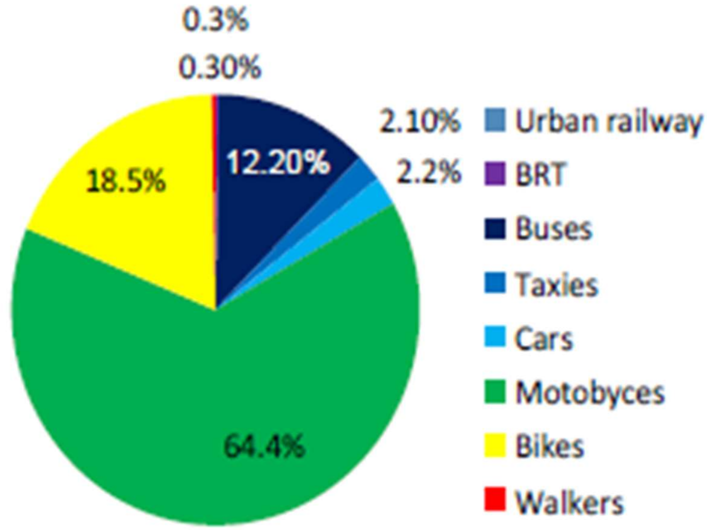

Figure 4-1 Modal Share in Hanoi (Source: TRAMOC – 2016)

In response to the escalating challenges of urban transport, the Vietnamese government initiated the development of the Urban Mass Rapid Transit (UMRT) system in 2008. This transformative plan envisions a future where motorcycles are eliminated by 2030, and public transport becomes the primary mode of commuting, offering a more efficient and sustainable way to travel in Hanoi. However, the implementation of this plan has been notably slow, marred by complicated clearance processes and numerous procedural problems. As of today, only Metro Line 2A is operational, and part of Metro Line 3 is scheduled to begin operations in late 2024. The pace of development has been sluggish, with only a fraction of the planned 14 metro lines making progress, reflecting the profound challenges in shifting Hanoi's transportation paradigm from motorcycle reliance to a more diversified and sustainable public transit system.

Figure 4-2 Hanoi’s proposed network of 14 urban railway lines

In response to the escalating challenges of urban transport, the Vietnamese government initiated the development of the Urban Mass Rapid Transit (UMRT) system in 2008. The comprehensive plan for Hanoi's metro network includes 14 lines, intended to cover key areas across the city to ensure broad accessibility. Figure 4-2 illustrates the routes plan of Hanoi UMRT development projects.

The ambitious plan aims to radically transform Hanoi's public transport landscape by eliminating motorcycles by 2030 and making public transport the primary mode of commuting. However, the implementation of this plan has been notably slow, marred by complicated clearance processes and numerous procedural problems. As of now, only Metro Line 2A is operational, and part of Metro Line 3 is scheduled to begin operations in late 2024. The pace of development has been sluggish, with only a fraction of the planned 14 metro lines making progress, reflecting the profound challenges in shifting Hanoi's transportation paradigm from motorcycle reliance to a more diversified and sustainable public transit system.

4.3. RHS emergence and development in Vietnam.

In the meantime, RHS like Uber and Grab launched in Vietnam around 2014, introducing a new dynamic mode not considered in earlier transport strategies. These services, unanticipated in previous strategies, have revolutionized urban mobility and significantly impacting the transport sector. A legal dispute in 2015 between Grab and Vinasun, a conventional taxi firm, concluded with Grab being held accountable, but required to pay only minimal compensation; no additional regulations were imposed. By 2018, after Uber's exit and sale of its market share to Grab, the latter solidified its position as the foremost RHS provider in Vietnam. The subsequent entry of competitors like

Be, Gojek, and FastGo diversified the market further. Figure 4-3 provides some name of leading providers of RHS in Vietnam.

Figure 4-3 RHS providers in Vietnam. Source: Internet

In 2019, Grab maintained its dominance, boasting around 45,000 MRHS and 35,000 CRHS vehicles in Hanoi. The rapid expansion of RHS, especially motorbike taxis, appears to contradict the policies that favor public transportation. While the Vietnamese government established regulatory conditions for transportation businesses in 2020, there were no specific policies to align RHS's growth with the city's traffic management objectives. This absence of regulatory oversight of RHS has sparked debate, particularly because these services might counteract traffic reduction objectives by promoting the use of motorbikes. By 2023, as aggressive pricing strategies began to subside, traditional taxi services embraced digital transformation by launching their own online booking platforms. The market also saw the introduction of electric vehicles for RHS, contributing to an evolving and somewhat uncertain landscape. Figure 4-4 and 4-5 offers some basic insights into the current state of RHS in Vietnam.

Figure 4-4. Car-based RHS. Source: Internet

Figure 4-5 Motorcycle-based RHS. Source: Internet

Figure 4-6 RHS electric vehicle adoptions. Source: Internet

The current scenario suggests that RHS, urban railways, and other public transport will continue to coexist. RHS prevalence in various countries indicates a global trend, regardless of the level of local public transport systems development. Investigating these trends of different RHS types, especially concerning traveler behavior, could inform government policy decisions, helping to integrate RHS effectively into Vietnam's broader transportation strategy. This integration is crucial, considering the delays and changes in public transport development compared to the original plans.

4.4. Survey area and Data Collection.

4.4.1. Survey area

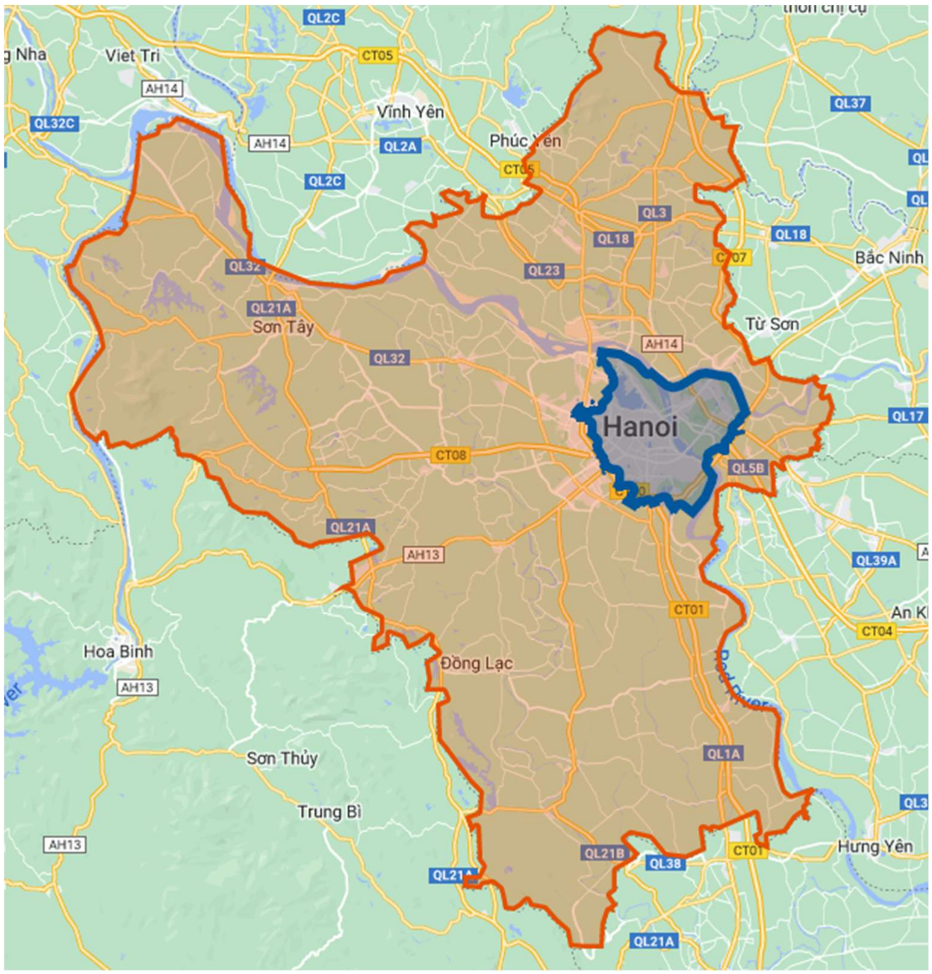

Figure 4-7 Survey area (blue zone) in Hanoi’s area (red zone)

As this study collected some data via questionnaires, we needed to select area to conduct the survey. A discussion was conducted with an associate professor in Vietnam, which were currently in the RHS research team collaborated with researchers from The University of Tokyo and Chulalongkorn University. Their projects are to study and compare the RHS across SEA countries. From the discussion, we decided the study area for the research. Figure 4-7 illustrates the location of survey area in the broader map of Hanoi. It encompasses nine inner-city districts of Hanoi, which are critical to understanding the urban transportation dynamics associated with RHS. These districts include Hoan Kiem, Hai Ba Trung, Ba Dinh, Dong Da, Cau Giay, Tay Ho, Long Bien, Hoang Mai, and Thanh Xuan. This selection was strategically made as these areas are expected to have a high activity level of RHS due to their urban characteristics and substantial residential and commercial presence.

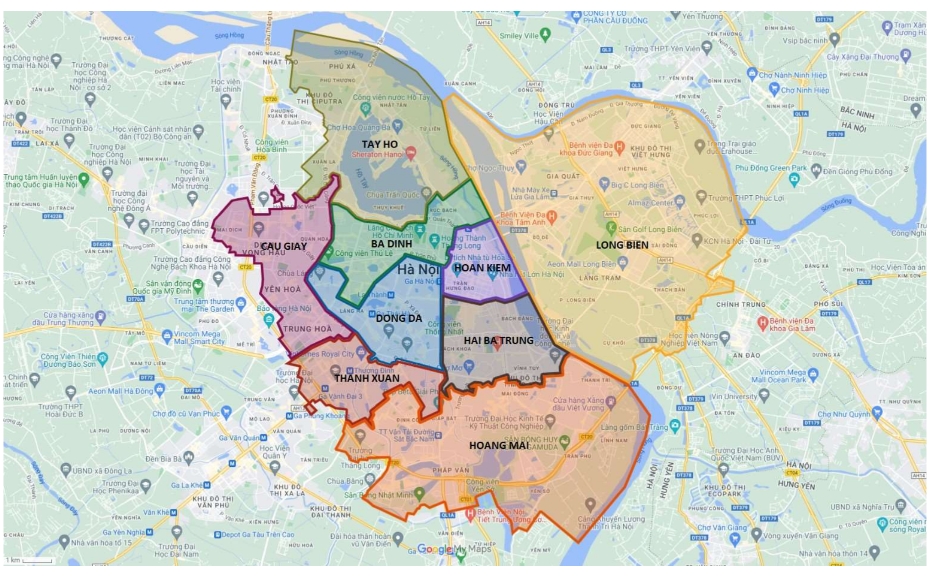

Figure 4-8 Nine inner-city districts in the survey area

These districts represent a mix of diverse urban settings within Hanoi, from densely populated commercial hubs to residential, educational and industrial zones. Each district provides unique insights into the behaviors and preferences of RHS users due to their varied socio-economic profiles and urban structures. For instance, Hoan Kiem, known for its bustling streets and historical significance, contrasts with the more residential and quiet areas like Thanh Xuan and Hoang Mai. Figure 4-8 describes the districts in survey area.

4.4.2. Questionnaires design

The questionnaire for this study is meticulously designed to capture a comprehensive range of data concerning RHS usage, travel activities, and demographic profiles of users within Hanoi's urban setting. The survey is divided into four main sections. The respondents were to participate in the survey and to answer a set of questions covering their demographic information such as gender, age, job, education level and income as well as their daily commute and information regarding RHS as well as Bus/MRT usage and perspectives:

- Social Demographic of Users

  This section collects basic demographic information about the participants, including gender, age, education level, occupation, income, marital status, and vehicle ownership. Additional details such as home address, work or study address, and current residency are also gathered to understand the geographic distribution and living conditions of the respondents, which might influence their travel behavior and transportation choices.

- Travel Activities of Users

Questions in this part focus on participants' general travel behavior. This includes their main travel mode, reasons for choosing their primary means of travel, and if applicable, their feeder mode to public transport. Historical data on previous main travel modes, daily and typical travel distances, trip chaining (sequence of trips without returning home), trip purpose, travel costs, and parking availability are also queried to provide insights into the comprehensive travel patterns of users.

- RHS Related Questions

Focused on the specifics of RHS usage, this section explores how frequently respondents use RHS, the purpose of these trips, and the possibility of using RHS as a feeder mode to public transport. It also assesses users' preferences during rush hour, their perceptions when RHS fares fluctuate, and their experiences in comparing RHS with personal vehicle use. This part is crucial for understanding the role and impact of RHS within the broader urban transport ecosystem in Hanoi.

- Bus/MRT Related Questions

This segment delves into users' assessments and perceptions of the bus and Metro train systems compared to other modes of transport. It investigates the maximum acceptable walking distance to a bus or MRT station, the likelihood of using the metro if the feeder mode is necessary, and the possibility of adopting different feeder modes if the walking distance to the station exceeds the acceptable limit.

4.4.3. Data collection

The methodology for data collection involves conducting surveys in a range of environments across these districts to capture a comprehensive view of RHS usage. Survey locations included supermarkets, residential areas, office buildings, universities, and busy streets, ensuring a broad spectrum of participants and usage scenarios. Physical (paper) forms of the questionnaire were used to accommodate the preferences of all participants and maximize response rates.

The target population included young and middle-aged individuals (18 to 60 years of age). Respondents were approached right after alighting from an RHS ride. The surveyor team, consisting of professionally trained individuals, conducted interviews, wrote down respondent’s answers and collected samples. To ensure a comprehensive and inclusive data set, the survey was carried out during a wide range of hours, from early morning at 7 am to evening at 9 pm, across all days of the week, thereby maximizing the potential for increased participation and a robust sample reflective of actual RHS usage patterns. A total of 500 valid responses were obtained.

The questions regarding our main areas of interest are as follows:

- The type of RHS commonly used: “Which type of RHS do you usually use?”
- Whether or not respondent choosing RHS to connect to train station if the walking distance to the station exceeds their maximum acceptable walking distance: “If the metro station is further than your acceptable walking distance, what transport would you use to get to that metro station to catch the train?”

- Motorcycle and car ownership: “How many of the following vehicles does you own?”
- Waiting time to use RHS: How long is your average waiting time to use RHS?
- Mode choice and reason of choosing to travel in rush hour: “ If you have to use RHS during the rush hour, which option do you prefer?” and “Which is the main reason for your choice?”

Chapter 5. Data and Preliminary Analysis

5.1. Respondents' socio-demographic profile

The characteristics of the respondents are summarized in Figure 5-1.

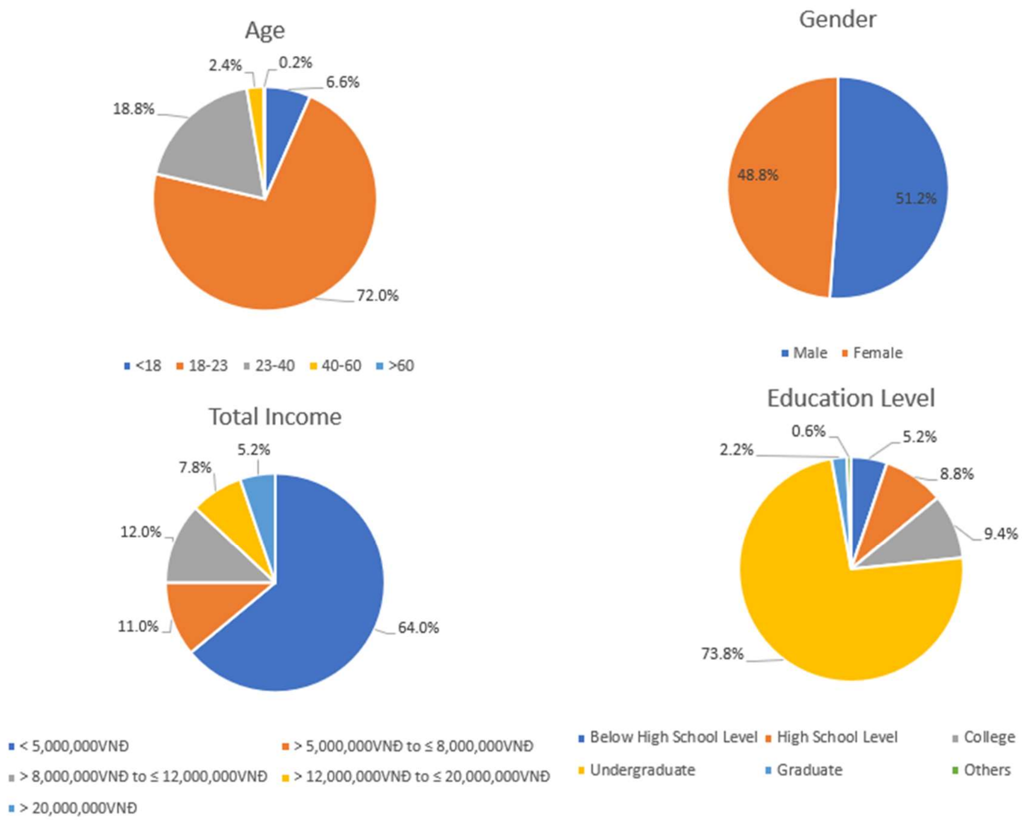

Figure 5-1 Respondents' socio-demographic (n = 500)

The demographic profile of the respondents is predominantly young, with over 70% under 23 years of age. This suggests a potential inclination towards RHS utilization among younger demographics. The gender distribution among the respondents is nearly balanced, with a male to female ratio of 51.2 to 48.8, which is reflective of the city's demographic proportion of nearly 50-50. A considerable majority of the respondents have undergraduate education level (73.8%), aligning with the income distribution where 75% report incomes below 8 million VND monthly. This sociodemographic profile suggests that RHS's affordability may be particularly appealing to younger individuals with limited financial resources.

According to the figure of Socio-Demographic Profile of Sample Respondents, it is reasonable to state that the survey data is able to represent the RHS population characteristics in Hanoi for further interpretation, analysis results and discussions revolve around RHS users.

5.2. Descriptive Statistic

The descriptive statistic is conducted for data set. It is used to present quantitative descriptions in a manageable form and simplify large amounts of data in a sensible way thereby allowing to observe and assess the consistency of the data and check if the data is normally distributed or not. It is also a necessary step to assess whether data can be used for further analysis.

Table 5-1 Descriptive statistics (n = 500)

Gender	male (51.2%); female (48.8%)
Age	less than 18 (6.6%); 18–23 (72%); 23–40 (18.8%); 46–60 (2.4%); more than 60 (0.2%)
Job	students (69.2%); office staff (9.4%); freelancer (12.4%); service industry worker (3.8%); government officer (4.2%); unemployed/retired (0.6%); housewife (0.2%); others (0.2%)
Education level	under high school level (5.2%); high school level (8.8%); college (9.4%); undergraduate (73.8%); graduate (2.2%); others (0.6%)

Monthly income (mil. VND)	less than 5 (64.0%); 5–8 (11.0%); 8–12 (12.0%); 12–20 (7.8%); more than 20 (5.2%)
Private vehicle ownership	no motorcycle or car (25.4%); motorcycle only (65%); car only (0.8%); both motorcycle and car (8.8%)
Regular travel mode	walking (6%); bicycle (4.2%); motorcycle (65.2%); electric bicycle (8.8%); conventional motorcycle taxi (0.2%); MRHS (0.8%); car (3.2%); taxi (0%); CRHS (0%); bus/BRT (10.0%); metro (1.2%); others (0.4%)
Type of RHS often used	only MRHS (53.4%); only CRHS (4%); both MRHS and CRHS (42.6%)
Frequency of using RHS	occasionally (53.6%); (less than) 1 time/week (22.8%); 2–3 times/week (21.0%); 4–5 times/week (0.8%); 6–7 times/week (1.0%); more than 7 times/week (0.8%)
Mode chosen to connect to metro station if the distance is too far to walk	bicycle (22.2%); electric bike (7.2%); motorcycle (18.4%); car (1%); conventional taxi (0.4%); bus (10.8%); MRHS (38.8%); CRHS (1.2%)
Mode chosen if having to use RHS/taxi during rush hour	MRHS (79.4%); CRHS (1.6%); conventional taxi (1.8%); catch Taxi/RHS right on the street (without using apps or hotline) (17.2%)
Reason for mode selection during rush hour	convenience (52.2%); accessibility (15.6%); availability (34.8%); time saving (36%); cost saving (38.6%)

Average waiting time to use MRHS (minutes)	Mean = 5.2; SD = 2.6; Min = 1.0; Max = 15.0
Average waiting time to use CRHS (minutes)	Mean = 7.7; SD = 4.4; Min = 1.5; Max = 30.0
Change in RHS usage due to past fare increase	no answer (39.2%); keep using (23.6%); switch to lower cost option (16%); use only when necessary (21.2%); reduction on frequency of use (0%); others (0%)
Change in RHS usage if current price increase by 15%	keep using (33.4%); switch to walking (4%); switch to public transport (29.2%); switch to motorbike/car (31.4%); switch to bike/electric bike (1.2%); others (1%)
Typical MRHS trip's travel distance (km)	Mean = 6.7; SD = 4.8; Min = 0.2; Max = 30.0
Typical CRHS trip's travel distance	Mean = 12.8; SD = 4.1; Min = 0.2; Max = 120.0
Travel time for the MRHS trip stated above (minutes)	Mean = 18.9; SD = 7.8; Min = 5.0; Max = 30.0
Travel time for the CRHS trip stated above (minutes)	Mean = 29.4; SD = 12.1; Min = 5.0; Max = 50.0
Travel cost (VND) of typical RHS trip	Mean = 14898; SD = 20125.85; Min = 8000; Max = 1000000
MRHS trip purpose	go to workplace/ school (13.2%); visit relatives, friends (10.3%); go to eat, drink (13.7%); go

	shopping, buying groceries (7.7%); pick up, drop off (15.8%); connect with bus, metro train (12.3%); go home (10.0%); go out, go to events (17.1%)
CRHS trip purpose	go to workplace/ school (9.5%); visit relatives, friends (18.1%); go to eat, drink (10.0%); go shopping, buying groceries (9.4%); pick up, drop off (16.3%); connect with bus, metro train (2.7%); go home (7.8%); go out, go to events (26.2%)
Accept to walk further to connect to use MRT (compare with bus/ BRT)	yes (78.6%); no (21.4%)
Consider using MRT in the future if new lines are opened with suitable travel route	yes (91.0%); no (9.0%)

Note: 1 million VND = 39.33 USD as of June 2024; SD: Standard Deviation.

The descriptive statistic on the survey data in this study is also called univariate analysis. Univariate analysis involves the examination across cases of one variable at a time. There are three major characteristics of a single variable which are the distribution, the central tendency, and the dispersion.

In the tables above, only the central tendency and dispersion for each of the variables were shown. The central tendency of a distribution is an estimate of the "center" of a distribution of values. The estimation of central tendency could be seen through the Mean (average) and the Median (which is the 50% in the Quartiles 25%-50%-75%) values. Dispersion refers to the spread of the values around the central tendency. The standard deviation (SD) is a measure of dispersion which shows the relation that set of scores has to the mean of the sample.

As can be seen in and across the tables, most of the variables have the values Mean and Median similar to each other. The same variable of different table also has the value which is not abnormal (significantly) difference with each other. Even though there should be Skewness and Kurtosis value to check the consistency of the data set, it is reasonable to stated that these descriptive statistic values or the survey data is normally distributed.

5.3. Preliminary Analysis

The preliminary analysis is introduced and conducted to check the reasonable of each hypothesis before continuing complicated analysis. There is one simple analysis for each hypothesis, respectively from hypothesis 1.

5.3.1. Hypothesis 1

The preliminary analysis of income distribution among users of MRHS and CRHS illustrates significant differences in how various income levels influence the choice between these two types of ride-hailing services. The income distribution for MRHS users shows a large majority (65.4%) earning below 5,000,000 VND, indicating that MRHS is predominantly used by lower-income individuals. In contrast, the income distribution for CRHS users is more varied, with the largest segment (57.5%) earning between 5,000,000 VND and 8,000,000 VND, and a substantial proportion (24%) earning above 8,000,000 VND. This suggests that CRHS appeals more to middle and higher-income users, who may value the additional comfort and privacy offered by cars. These findings validate the hypothesis that income levels significantly impact the choice between MRHS and CRHS, supporting the need for further nuanced analysis to understand the underlying preferences and constraints influencing these decisions.

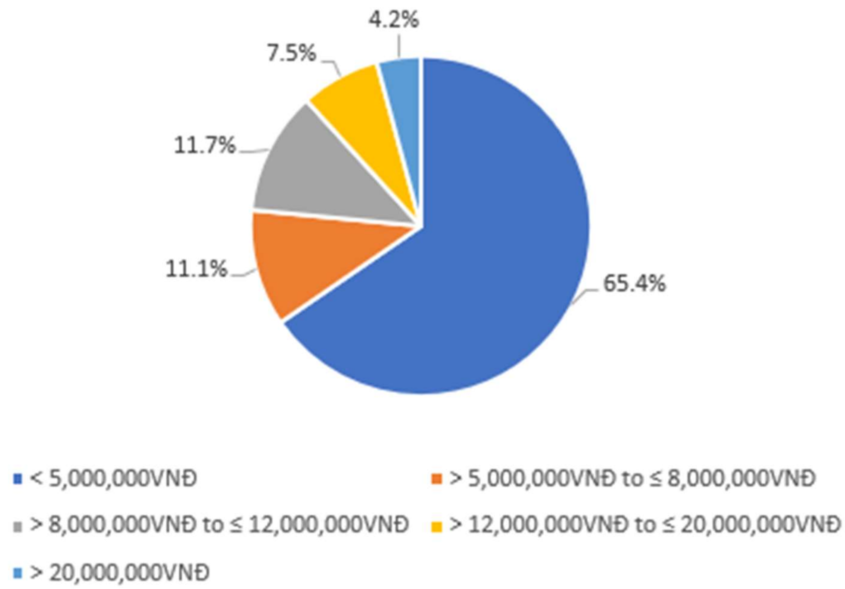

Figure 5-2 Income Distribution of MRHS Users (per month) (n =480)

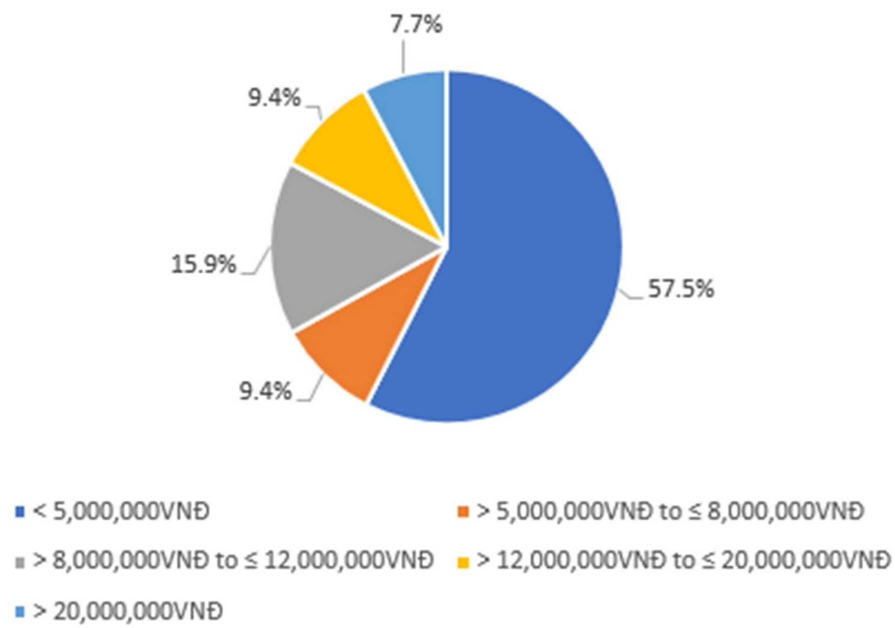

Figure 5-3 Income Distribution of CRHS Users (per month) (n = 233)

5.3.2. Hypothesis 2

The preliminary analysis for Hypothesis 2 provides compelling insights into the roles of motorcycle-based and car-based ride-hailing services (RHS) as feeder modes to public transit. According to question about trip purpose, 186 out of 497 respondents (37%), currently use motorcycle RHS to connect to public transit, markedly higher than the 21 respondents using car RHS for the same purpose. This suggests a stronger inclination towards using MRHS over CRHS for linking with public transport systems, likely due to the flexibility and ease of navigating traffic that motorcycles provide.

Furthermore, the survey data reveal that a substantial 78.6% of respondents are willing to walk further to access Metro Rail Transit (MRT) systems compared to buses or Bus Rapid Transit (BRT), indicating a preference for the MRT despite potentially longer initial or final walking segments. When considering the future use of MRT, an overwhelming 91% of participants expressed their intention to use it, which underscores the anticipated shift towards more sustainable and efficient mass transit options in urban settings.

Additionally, when faced with a walking distance to the metro station that exceeds their acceptable limit, a significant proportion of respondents (38.8%) prefer motorcycle RHS as a feeder mode. This preference for MRHS as a link to the metro stations further emphasizes its potential role in enhancing the accessibility of public transit systems by bridging the gap between the metro stations and the commuters' starting or ending points. These findings substantiate the hypothesis that MRHS can effectively function as both an initial and final mode of transportation for accessing public transit, whereas CRHS shows less utility in this regard.

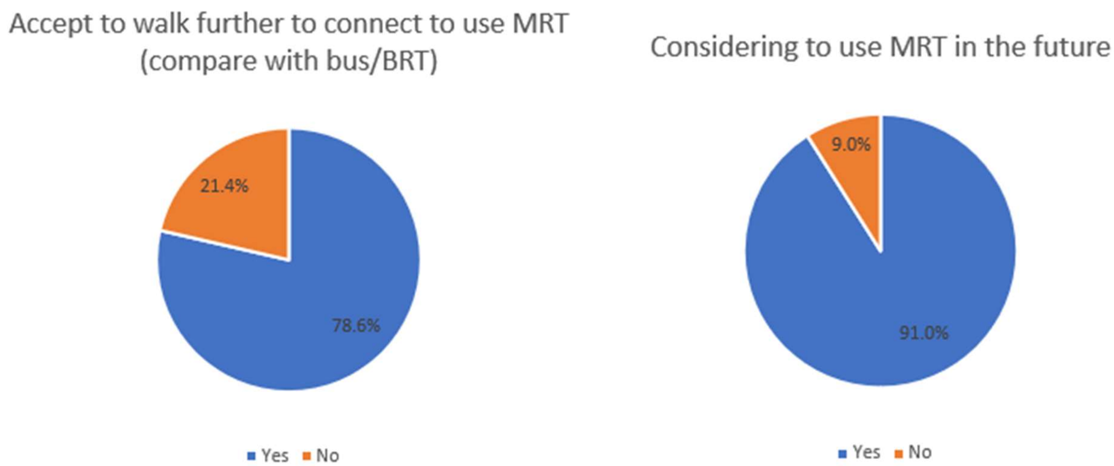

Figure 5-4 Public transportation preferences of respondent (n = 500)

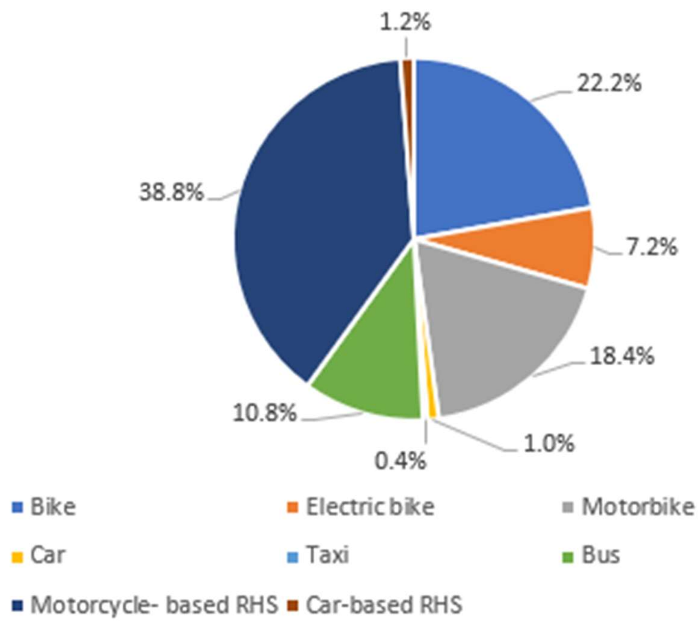

Figure 5-5 Commuter mode choice to connect to station if acceptable walking distance is exceeded (n = 500)

5.3.3. Hypothesis 3

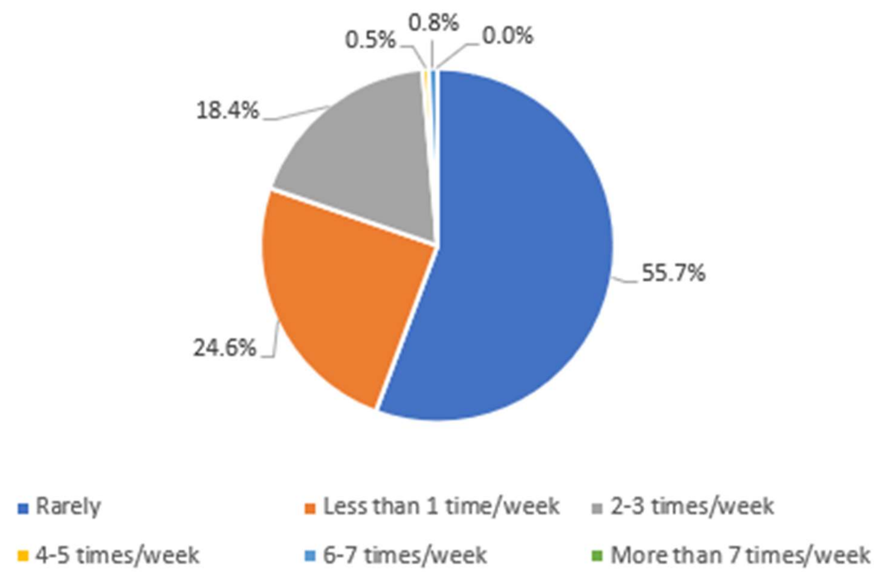

Figure 5-6 Motorcycle owner's frequency of RHS usage (n = 369)

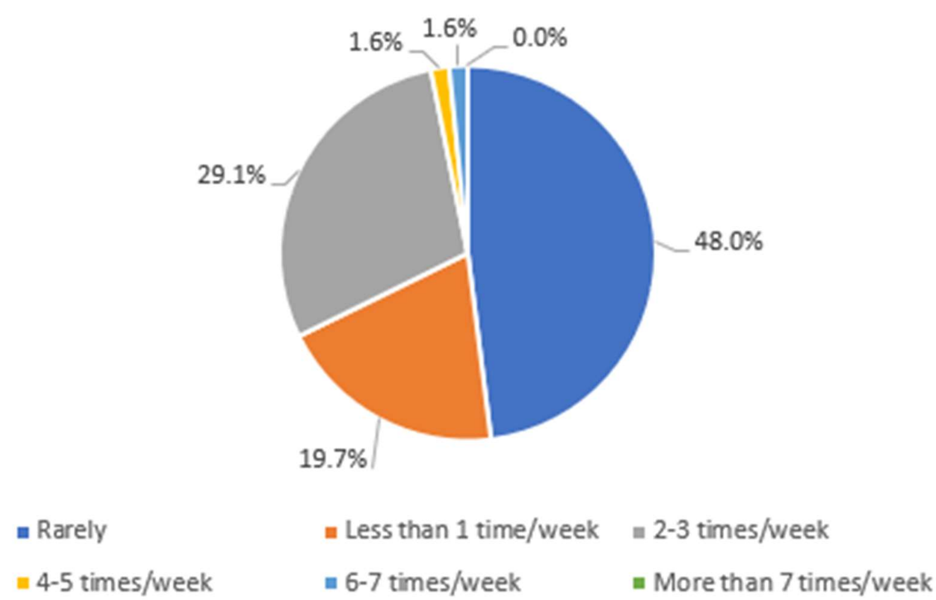

Figure 5-7 Car owner's frequency of RHS usage (n = 48)

Hypothesis 3 evaluates the impact of vehicle ownership on the usage frequencies of RHS, differentiating between motorcycle and car owners. The analysis reveals that car owners, represented in the Figure 5-7, display a varied pattern of RHS use: 48.0% of them rarely utilize RHS, indicating that car generally meet their daily transportation needs. However, a notable proportion, 29.1%, relies on RHS two to three times per week.

In contrast, the Figure 5-6 shows that motorcycle owners have a lower frequency of RHS usage, with 55.7% using these services rarely. This lower usage rate among motorcycle owners suggests that the comprehensive utility provided by motorcycle reduce the dependency on additional transportation services. The number of motorcycle owners use RHS regularly, with 18.4% using it two to three times per week and 24.6% even less frequently, further emphasizing the sufficiency of motorcycle for most travel needs.

These findings substantiate Hypothesis 3 by illustrating the possible of distinct RHS usage patterns based on the type of vehicle owned. However, to further explore influence of the motorcycle ownership to MRHS usage and the car ownership to CRHS usage, a more advanced analysis technique is required.

5.3.4. Hypothesis 4

Hypothesis 4 proposes that during rush hour, commuters have a pronounced preference for MRHS over CRHS due to shorter waiting times. Figure 5-8 shows respondents' choice if they have to use one of these service during the rush hour. The graph clearly supports this proposition, showing that a significant 79.3% of RHS usage during peak traffic periods is accounted for by MRHS. This preference is likely driven by the efficiency of motorcycles in navigating congested traffic, which substantially reduces commute times compared to cars. Conversely, only 1.8% of ride-hailing involves cars, with an additional 1.6% using taxis, whether hailed directly on the street or via an app.

This indicates a strong commuter preference for the speed and convenience of motorcycles over the potentially slower and more cumbersome cars during high-traffic periods.

The data also highlights a niche but notable behavior where a small fraction of users (1.6%) opt to wave down taxis or RHS directly from the street, bypassing app-based booking systems. This behavior could indicate a demand for the quickest possible solutions to commuting challenges, underscoring the urgency and immediacy typical of rush-hour transportation needs.

Overall, the dominance of MRHS during rush hour and the minimal use of CRHS and taxis corroborate Hypothesis 4, making it a reasonable assertion for further detailed investigation. Further analysis could delve into the specifics of waiting times, commuter satisfaction, and the operational dynamics of RHS during peak times to flesh out the strategic implications for urban transportation planning and the ride-hailing industry. This foundational understanding is crucial for enhancing the effectiveness of RHS in meeting urban mobility demands during critical commuting periods.

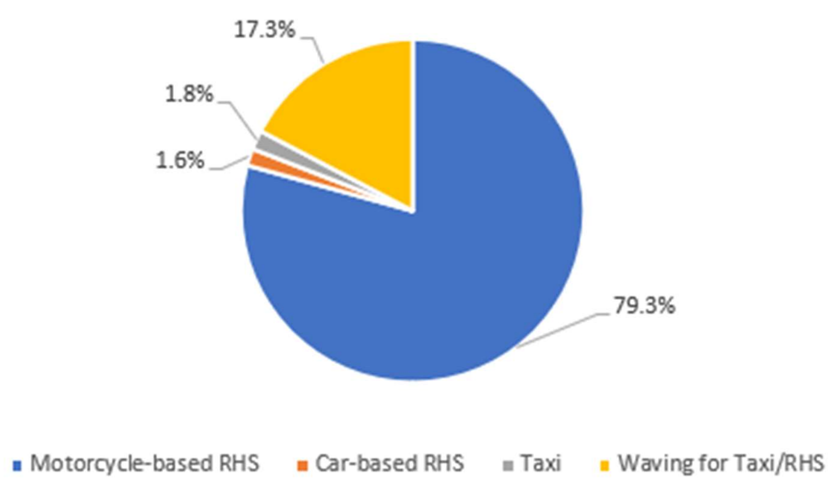

Figure 5-8 Mode choice during the rush hour (n = 500)

5.3.5. Hypothesis 5

Hypothesis 5 posits that MRHS users are more susceptible to the impact of fare increases CRHS users. The data provided in the graphs shed light on how fare increases have historically affected RHS usage for both groups, and how they might respond to future increases.

The first set of pie charts in Figure 5-9 and 5-10 reveals the immediate past responses of MRHS and CRHS users to fare increases. For MRHS users, only 43.4% would continue to use the service at the same rate despite past fare increases, while 33.6% switched to lower-cost options and 23% reduced their frequency of use. This indicates a significant sensitivity to price changes among MRHS users, as a majority adjusted their usage behavior in response to fare hikes.

Conversely, CRHS users displayed a slightly stronger loyalty to their service choice; 50% stated they would keep using the service despite fare increases, with 42.9% continuing to use the service only when necessary, and a small fraction, 7.1%, switching to lower-cost options. This suggests that CRHS users, perhaps due to the higher initial cost tolerance associated with car rides, exhibit less sensitivity to price increases compared to MRHS users.

The second set of pie charts in Figure 5-11 and 5-12 projects potential future behaviors in response to a hypothetical 15% fare increase. Among MRHS users, a significant shift is evident, with only 29.2% willing to continue using RHS under increased costs, and a notable 36.7% considering switching to public transport. The rest would switch to more economical transport modes such as walking or biking. For CRHS users, 45% would still stick with RHS after a 15% fare increase, indicating a higher threshold for price elasticity. About 30% would switch to public transport, suggesting some sensitivity, but less than that observed among MRHS users.

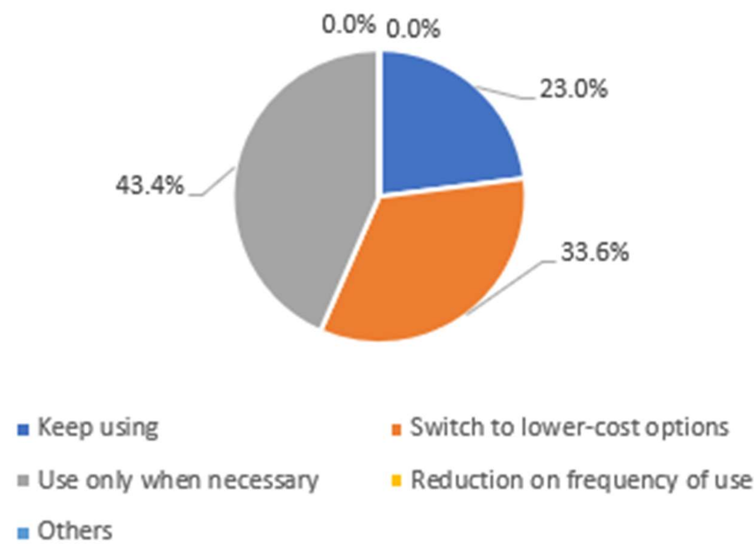

Figure 5-9 MRHS user responses for past fare increases (n = 152)

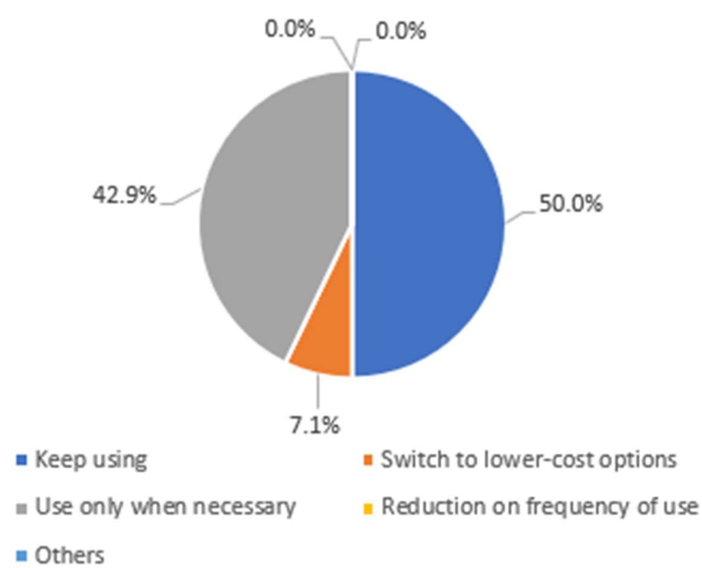

Figure 5-10 CRHS user responses for past fare increases (n = 26)

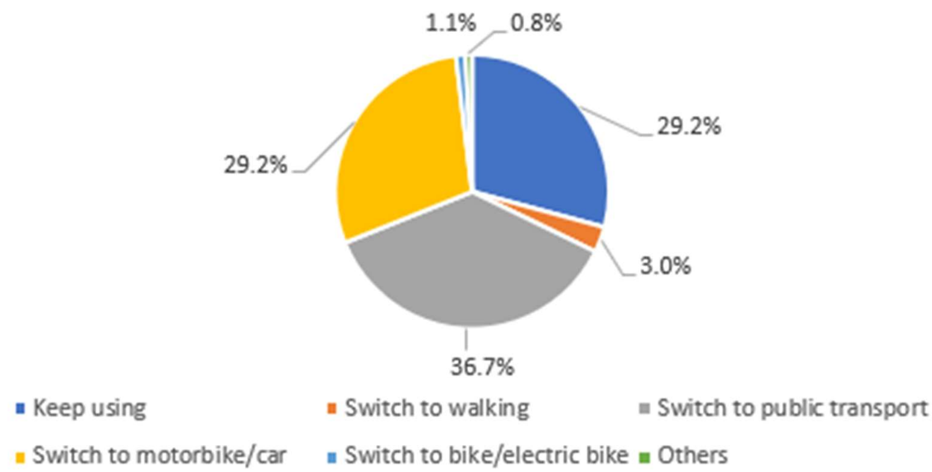

Figure 5-11 MRHS user responses for future 15% fare increases (n= 480)

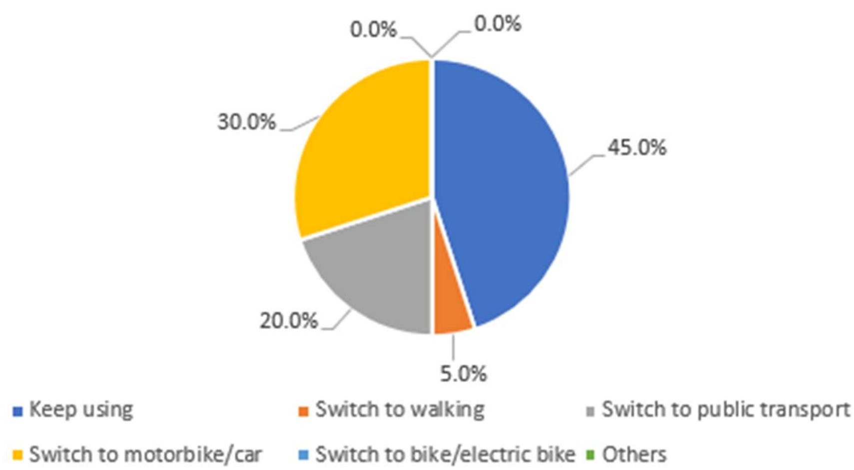

Figure 5-12 CRHS user responses for future 15% fare increases (n = 233)

These findings substantiate Hypothesis 5 by demonstrating that MRHS users are indeed more vulnerable to fare increases than CRHS users, likely due to the generally lower cost thresholds and alternative transport options available to them. This analysis highlights the need for further investigation into the pricing strategies of RHS providers and how they could affect user retention and service accessibility, particularly for those dependent on MRHS for their daily commutes.

Chapter 6. Results and Discussion

6.1. Analysis Results

6.1.1. Hypothesis 1 and 2

Table 6-1 presents the results of estimating a bivariate binary probit model for Hypotheses 1 and 2. In this estimation, the two dependent variables are "MRHS," which is assigned a value of one if a respondent frequently uses MRHS, and zero otherwise, and "CRHS," which is assigned a value of one if a respondent frequently uses CRHS, and zero otherwise. The independent variables include "Gender," with a value of one for male respondents and zero for female respondents; "Age," which is the respondent's age in ascending ordinal categories with the value from one to five; "Education," which is the respondent's level of education in ascending ordinal categories with the value from one to six; "Income," which is the respondent's income in ascending ordinal categories with the value from one to five; "Ownership," with a value of one if the respondent owns a private vehicle, and zero otherwise; and "RHSConnect," assigned a value of one if the respondent would select RHS to connect to a metro station when it is too far to walk, and zero otherwise.

The Variance Inflation Factor (VIF) is used to detect multicollinearity within regression models. According to James et al. (2013), VIF values exceeding 10 indicate high multicollinearity, warranting further investigation or corrective measures. As can be seen from Table 6-1, all of variables’ VIF are below the threshold which suggests the model does not suffer from severe multicollinearity issues that would compromise the reliability of the regression coefficients.

For Hypothesis 1, the coefficient for income in relation to MRHS is -0.305, with a significant p-value of 0.002, indicating that an increase in income is associated with a lower probability of MRHS use. In contrast, the income coefficient for CRHS is 0.140 with a p-value of 0.025, suggesting that higher income increases the likelihood of CRHS use. The distinct effects of income on MRHS and CRHS use, as demonstrated by the model's coefficients, support Hypothesis 1.

Hypothesis 2 posits that MRHS is more likely to be selected as a transport option for connecting to public transport, while CRHS may not be as preferred. The positive coefficient for MRHS (0.502) with a p-value of 0.045 suggests that respondents are inclined to use MRHS when the metro station is beyond walking distance. Conversely, the coefficient for RHSConnect is negative for CRHS (-0.382), with a highly significant p-value of 0.001, indicating a clear reluctance to use CRHS for metro station connectivity when the distance is too far to walk. These coefficients for RHSConnect support Hypothesis 2.

Table 6-1 Results of BP estimation for H1 and H2

	MRHS		CRHS		VIF
	Coefficient	S.E	Coefficient	S.E	
Intercept	2.289***	0.655	-0.853**	0.345	
Gender	-0.090	0.209	0.121	0.115	1.02
Age	0.213	0.248	0.001	0.135	1.83
Education	-0.150	0.140	0.111	0.069	1.16
Income	-0.305***	0.100	0.140**	0.062	1.75
Ownership	0.151	0.293	0.114	0.147	1.26

RHSConnect	0.502**	0.251	-0.382***	0.118	1.02
Correlation (ρ)	-0.437***	0.122			
Number of Observations	500				
Wald Chi-square (12)	41.28	Prob>Chi-square = 0.0000			
Log-likelihood	-408.794				
AIC	847.588				
McFadden’s Pseudo R^2	0.495				

Note: ***: p < 0.01; **: p < 0.05; *: p < 0.1. AIC: Akaike's Information Criterion. VIF: Variance Inflation Factor

The correlation (ρ) is significant which indicates the high relation between the error terms of MRHS and CRHS. In other words, the chosen BP models in this case is correct and the results has much more meaning rather than performing two separate binary regression model.

6.1.2. Hypothesis 3

Table 6-2 shows the results of the BOP model for Hypothesis 3, as outlined by Greene (2012). This model estimates the frequency with which respondents use MRHS (FreqMRHS) and CRHS (FreqCRHS). Both "FreqMRHS" and "FreqCRHS" are ordinal variables, categorized in ascending order based on the number of times respondents use RHS per week, with the value from zero to six. We include the covariates "OwnershipM" and "OwnershipC" to better explore the hypothesis, which aims to examine the relationship between motorcycle ownership and the use of MRHS, and to compare it with car ownership and the use of CRHS. "OwnershipM" is assigned a value of one if the respondent owns a motorcycle, and zero otherwise;

similarly, "OwnershipC" is assigned a value of one if the respondent owns a car, and zero otherwise. This approach transforms the model into what is known as a "Seemingly unrelated bivariate ordered probit model."

The negative coefficient for motorcycle ownership, at -0.236 with a p-value of 0.05, indicates that owning a motorcycle is linked to a lower probability of using MRHS. Conversely, the positive coefficient for car ownership (0.397) with a p-value of 0.048 suggests that car owners are more likely to use CRHS. These contrasting effects support Hypothesis 3, which posits that vehicle ownership affects the frequency of using the respective RHS, showing an inverse relationship between owning a motorcycle or a car and the usage of the corresponding RHS.

The correlation (ρ) is significant, which further confirm that the use of the BOP method is reasonable, and the results are reliable in this situation.

Table 6-2 Results of BOP estimation for H3

	FreqMRHS		FreqCRHS		VIF
	Coefficient	S.E	Coefficient	S.E	
Intercept	1.609***	0.294	-0.822***	0.308	
Gender	-0.046	0.098	0.023	0.103	1.02
Age	-0.005	0.113	0.016	0.119	1.83
Education	0.092	0.058	0.135**	0.061	1.16
Income	-0.007	0.052	0.090	0.061	2.32
OwnershipM	-0.236**	0.120	—	—	1.23
OwnershipC	—	—	0.397**	0.201	1.56
Threshold					

1|2	0.193***	0.284	1.500***	0.311
2|3	0.814***	0.286	2.017***	0.317
3|4	2.074***	0.304	3.201***	0.364
4|5	2.398***	0.311	3.427***	0.374
5|6	2.604***	0.342	3.563***	0.393
Correlation (ρ)	0.212***	0.053		
Number of Observations	500			
Wald Chi-square (5)	6.05	Prob>Chi-square = 0.0016		
Log-likelihood	-1210.631			
AIC	2467.262			
Pseudo R-squared	0.183			

Note: ***: p <0.01; **: p <0.05; *: p <0.1. — Not relevant

6.1.3. Hypothesis 4

Table 6-3 presents the results of the MNL regression analysis for Hypothesis 4. The regression's dependent variable is the transportation mode chosen by respondents during rush hour, which includes options such as MRHS, CRHS, a taxi, or directly using a taxi or RHS. These choices are assigned the value of one, two, three and four, respectively. MRHS is used as the reference category to facilitate comparison with CRHS.

The terms "D_{MRHS}" and "D_{CRHS}" are used as dummy variables to categorize the data of travelers who use either MRHS exclusively, CRHS exclusively, or both services. "D_{MRHS}" which is assigned a value of one if a respondent frequently uses MRHS, and zero otherwise, and "D_{CRHS}" which is assigned a value of one if a respondent frequently uses CRHS, and zero otherwise. Additional independent variables include "WT_{MRHS}," which represents the waiting time for MRHS; "WT_{CRHS}," which represents the waiting time for CRHS; and "RConve," "RAccess," and "RAvail," which denote the reasons for choosing an alternative mode, corresponding to convenience, accessibility, and availability, with the value of one if that reason is selected, and zero otherwise.

We received three sets of regression results as we specified MRHS as the base outcome.

$$\log\left(\frac{\pi_2}{\pi_1}\right) = \alpha + \beta_{12}X_{age} + \beta_{22}X_{gender} + \beta_{32}X_{income} + \beta_{42}X_{Education}$$
$$+ \beta_{52}X_{Ownership} + D_{MRHS}.\beta_{62}X_{WTMRHS}$$
$$+ D_{CRHS}.\beta_{72}X_{WTCRHS} + \beta_{82}X_{R.Avail} + \beta_{92}X_{R.Access}$$
$$+ \beta_{102}X_{R.Conve} + \varepsilon_{12}$$

$$\log\left(\frac{\pi_3}{\pi_1}\right) = \alpha + \beta_{13}X_{age} + \beta_{23}X_{gender} + \beta_{33}X_{income} + \beta_{43}X_{Education}$$
$$+ \beta_{53}X_{Ownershi} \quad + D_{MRHS}.\beta_{63}X_{WTMRHS}$$
$$+ D_{CRHS}.\beta_{73}X_{WTCRHS} + \beta_{83}X_{R.Avail} + \beta_{93}X_{R.Access}$$
$$+ \beta_{103}X_{R.Conve} + \varepsilon_{13}$$

$$\log\left(\frac{\pi_4}{\pi_1}\right) = \alpha + \beta_{14}X_{age} + \beta_{24}X_{gender} + \beta_{34}X_{income} + \beta_{44}X_{Education}$$

$$+ \beta_{54}X_{Ownershi} \quad + D_{MRHS}.\beta_{64}X_{WTMRHS}$$

$$+ D_{CRHS}.\beta_{74}X_{WTCRHS} + \beta_{84}X_{R.Avail} + \beta_{94}X_{R.Access}$$

$$+ \beta_{104}X_{R.Conve} + \varepsilon_{14}$$

The negative coefficient for DMRHS × WTMRHS (-0.552), significant at the 1% level, indicates that as waiting times increase, commuters who only use MRHS are likely to keep preferring MRHS over CRHS. The positive coefficient for DCRHS × WTCRHS (0.146), significant at the 5% level, suggests a similar pattern for those who only use CRHS, continuing to favor CRHS over MRHS as waiting times increase. Additionally, for commuters who use both types of RHS, the stronger coefficient for MRHS compared with the CRHS coefficient signifies a general preference for MRHS over CRHS in the event of longer waiting times. Together, these results provide strong support for H4.

An interesting notice is that some travelers choose to catch taxis or RHS directly from the street, mainly because of their immediate availability (with a coefficient of 1.790 and significant at 1%).

Table 6-3 Results of BOP estimation for H4

MRHS (base outcome)	CRHS		Taxi		Directly catch Taxi/RHS		VIF
	Coef.	S.E	Coef.	S.E	Coef.	S.E	
Intercept	-2.489	3.023	-3.210	2.058	-3.889***	1.006	
Gender	-0.406	0.777	0.904	0.776	-0.309	0.263	1.03
Age	1.000	0.924	0.704	0.622	0.450	0.288	1.82
Education	0.099	0.605	-0.775**	0.331	0.257*	0.180	1.12
Income	-0.551	0.466	-0.074	0.352	-0.065	0.129	1.75
D_{MRHS} (1/0) x WT_{MRHS}	-0.552***	0.191	-0.235	0.166	0.029	0.051	1.18
D_{CRHS} (1/0) x WT_{CRHS}	0.146**	0.072	-0.016	0.086	-0.009	0.030	1.13
RConve	-1.483*	0.865	-0.077	0.744	-0.147	0.263	1.04
RAccess	-0.850	1.228	-0.399	1.207	0.377	0.335	1.06
RAvail	-2.489	1.146	0.815	0.731	1.790***	0.268	1.03
No. of Observations	500						
LR Chi-Square (27)	91.69		Prob > chi-square =	0.0000			
Log-likelihood	-266.3508						
AIC	592.702						
Hit Ratio	0.796						
McFadden's Pseudo R-squared	0.1468						

Note: ***: p < 0.01; **: p < 0.05; *: p < 0.1.

6.1.4. Hypothesis 5

Table 6-4 presents the results of the logit regression analysis for Hypothesis 5. The regression's dependent variable is generated from user's response to hypothetical future fare increase. The "FareInc" variable is assigned a value of zero if a respondent keeps using RHS, and one if respondent switch to use another mode of transport. The independent variables include "Gender," with a value of one for male respondents and zero for female respondents; "Age," which is the respondent's age in ascending ordinal categories with the value from one to five; "Education," which is the respondent's level of education in ascending ordinal categories with the value from one to six; "Income," which is the respondent's income in ascending ordinal categories with the value from one to five; "Ownership," with a value of one if the respondent owns a private vehicle, and zero otherwise; "Travel Cost" is the respondent's reported travel cost of typical RHS trip; $TToTD_{MRHS}$ and $TToTD_{CRHS}$ is travel time over travel distance of MRHS and CRHS, respectively.

Table 6-4 Results of logit estimation for H5

FareInc	Coefficient	S.E	t-stat	sig
Intercept	4.128	1.035	5.66	***
Gender	0.968	0.070	-0.45	
Age	0.792	0.051	-3.63	***
Education	1.156	0.039	4.26	***
Income	1.037	0.068	0.56	
Ownership	0.999	0.093	-2.35	***
TravelCost	0.744	0.001	-4.87	**

$TToTD_{MRHS}$	0.981	0.020	-0.94	
$TToTD_{CRHS}$	0.950	0.011	-4.40	***

Note: ***: p < 0.01; **: p < 0.05; *: p < 0.1.

A "TravelCost" coefficient of 0.745, significant at 5%, suggests that for each unit increase in travel costs, the likelihood of switching to another mode of transport (rather than continuing to use RHS) increases. The odds of switching are exp(0.745) times higher for each unit increase in travel cost. This points to a positive relationship where higher travel costs are associated with a greater tendency to abandon RHS in favor of alternative transportation options. It is clear evidence that RHS users are influence by fare increase through travel cost. As a result, if the respondents use RHS often, the effect seemed to be even larger since now fare increase have a direct impact on their travel cost.

Table 6-5 provide additional information regarding how different travel cost affect MRHS and CRHS. BP models is used to discuss the MRHS and CRHS usage. (similar to hypothesis 1)

Table 6-5 Results of BP estimation for H5

	MRHS		CRHS		VIF
	Coefficient	S.E	Coefficient	S.E	
Intercept	2.533***	0.665	-1.002***	0.339	
Gender	-0.128	0.213	0.102	0.115	1.02
Age	0.147	0.259	0.019	0.134	1.84
Education	-0.122	0.142	0.104	0.069	1.17
Income	-0.207*	0.109	0.127**	0.065	1.93

Ownership	0.203	0.292	0.065	0.147	1.27
TravelCost	-0.012***	0.001	0.004	0.003	1.21
Correlation (ρ)	-0.476***	0.115			
Number of Observations	500				
Wald Chi-square (12)	38.72	Prob>Chi-square = 0.0001			
Log-likelihood	-409.576				
McFadden's Pseudo R^2	0.477				

As can be seen, Travel Cost is negatively related to the adoption of MRHS. In other words, as the travel cost increases, the likelihood of using MRHS decreases. (significant is at 1% level)

Travel Cost has weaker relation to CRHS adoption. The results are also not statistically significant which indicated there isn't strong evidence about the effect of travel cost increase to CRHS or travel cost does not have much effect on the adoption of CRHS.

It is reasonable to consider H5 is supported though the bridging of the influence of fare increases to the travel cost and the difference relation between travel cost to MRHS and CRHS.

6.2. Discussion

This study is one of the first to investigate the heterogeneity impacts of different types of RHS on commuter travel behaviors. Various points of interest considering contrasting influences of MRHS versus CRHS have been highlighted. Firstly, income levels have distinct impacts on the use of MRHS and CRHS, with each service being favored differently by income segments.

Secondly, the tendency of MRHS to serve as a connector to public transport, a role less commonly filled by CRHS. Thirdly, the research found that owning a motorcycle decreases the likelihood of using MRHS, while owning a car increases the likelihood of opting for CRHS. Finally, it was proved that during rush hours, MRHS is often preferred over CRHS due to its expedited service.

First, our empirical analysis supports H1. As individual income increases, there is a significant decrease in the log odds of using MRHS and a corresponding increase in the log odds of using CRHS. It suggests that income level is a significant factor in determining the use of MRHS and CRHS. The observed pattern may be attributable to the differential pricing of MRHS and CRHS, which seems to target distinct socio-economic segments. Typically, MRHS may be the more cost-effective option, aligning with the necessities of lower-income individuals who are often more sensitive to price. In higher-income brackets, individuals might prefer CRHS which likely offers additional benefits such as greater comfort, privacy, and the perception of elevated status associated with personalized car travel. This finding suggests that policies related to travel costs for MRHS and CRHS should be different. For example, tiered support programs could be developed, offering discounts for MRHS to lower-income individuals and ensuring high standards for CRHS preferred by higher-income groups.

Second, based on our empirical analysis, H2 is also supported. The potential of MRHS as an effective first and last mile solution can be linked to its inherent advantages, including flexibility, ease of navigation in dense urban areas, and cost-effectiveness. Hanoi, where narrow streets and high traffic volumes can hinder the movement of larger vehicles, motorcycles offer superior agility. This makes MRHS particularly apt for short-distance trips that connect commuters from their homes or workplaces to public transport hubs. In contrast, CRHS may not be as well-suited for this role due to its relatively higher costs and its tendency to contribute to traffic congestion during peak hours. Consequently, MRHS could be arguably considered a complementary addition to public transport, whereas CRHS may serve as a substitutive option. This finding could explain the non-consensus results of previous studies regarding RHS effects to transit and confirm the idea of RHS could hold both complementary and substitutive effects by Felipe F. Dias, (2021). Such finding suggests that policies should aim to enhance the integration of MRHS with the public transit network, improving first and last-mile connections. Strategies could include establishing designated pick-up and drop-off zones adjacent to transit stations, facilitating seamless transitions for commuters. Additionally, with the advent of environmentally friendly vehicles in the RHS market, the installation of charging stations at metro stations may incentivize the use of electric and low-emission RHS vehicles.

Third, H3 is also supported, suggesting a behavioral pattern regarding vehicle ownership and RHS usage. Owning a motorcycle decreases the likelihood of utilizing MRHS, possibly because of the convenience and immediate availability of using personal motorcycles, reducing reliance on MRHS. Contrariwise, RHS is also proven to have effects on reducing vehicle ownership (Contreras & Paz, 2018). The correlation between car ownership and an augmented propensity to utilize CRHS can be partly attributed to the car owners' affinity for the automotive travel experience. The comfort, personal space, and amenities offered by car travel make CRHS particularly appealing to these individuals. Furthermore, in contexts where car ownership is emblematic of social status, the preference for CRHS may reflect the owners' lifestyle and social standing. Opting for CRHS enables car owners to experience the advantages of car travel without engaging in the act of driving, free from its incumbent obligations and potential challenges. This could highlight a transition from motorcycles to cars in society. Given the inverse relationship between motorcycle ownership and MRHS utilization, promoting the MRHS-metro link as a cost-effective alternative to private vehicle use could stimulate a modal shift toward public transport.

Fourthly, H4 is supported by our analysis. It appears that during rush hours, commuters who exclusively utilize either MRHS or CRHS tend to remain consistent with their respective choices. However, among those who avail themselves of both services, there is a discernible preference for MRHS over CRHS during peak traffic periods. This pattern may be explained by the time sensitivity of MRHS users, who prioritize the ability to navigate swiftly through traffic congestion. On the other hand, individuals who exclusively use CRHS do not exhibit the same level of time sensitivity; they are more inclined to tolerate increased waiting times, maintaining their loyalty to CRHS even when faced with delays. Hoang-Tung et al., (2022) have also observed this phenomenon, albeit from the perspective of overall travel time. Notably, our analysis of H4 reveals that a subset of travelers opts for hailing taxis or RHS directly from the street, primarily due to immediate availability (with a coefficient of 1.790, significant at the 1% level). This indicates a preference for the immediate procurement of transportation without the intermediary step of phone or hotline ordering, a behavior that is well-observed in the field of transportation. This finding indicates the necessity for establishing designated areas for RHS pick-up and drop-off (waiting zones), particularly for MRHS. Implementing such zones could mitigate the practice of hailing rides on the street, which has the potential to exacerbate traffic congestion.

Finally, when the fare increases by 15%, “travel cost” has a positive association with increasing the chance of people switching from using RHS to other modes of transport. This indicates that as the fare increases, people tend to switch to other modes, possibly to their personal vehicle if they own one. It also confirms that “travel cost” is negatively related to the adoption of MRHS but does not have much effect on CRHS adoption. The hypothesis “MRHS users are more susceptible to the impact of fare increases than CRHS users” is supported. Such understanding could benefit both the RHS providers and public-sector stakeholders. As for RHS providers, changes in pricing strategies affect MRHS users more significantly. Additionally, MRHS has proven in a previous hypothesis that it could serve as first- and last-mile options for public transport while CRHS served as a substitute option. Therefore, for policymakers, if price strategies from the government directed towards MRHS use, will be more effective and beneficial favoring Hanoi's developing public transport system plans.

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Chapter 7. Conclusions and Recommendations

7.1. Conclusions

This study provides a comprehensive analysis of the factors influencing commuter preferences for MRHS and CRHS in the urban transport system of Hanoi, Vietnam. Utilizing a robust dataset, econometric models such as Bivariate Probit, Bivariate Ordered Probit, and Multinomial Logit Regression Models were employed to elucidate the dynamics impacting ride-hailing usage. The findings highlight several crucial insights: firstly, income levels significantly influence the choice between MRHS and CRHS, with higher income groups favoring the comfort and status of CRHS, while lower-income commuters prefer the cost-effective and flexible MRHS. Secondly, the study confirms MRHS's effectiveness in providing first and last-mile connectivity, essential for bridging gaps in public transportation networks, unlike CRHS, which is less effective in these roles due to higher costs and reduced maneuverability in traffic. Thirdly, a distinct relationship was observed between personal vehicle ownership and ride-hailing preferences; motorcycle owners are less likely to choose MRHS, possibly because their personal vehicles already fulfill their urban mobility needs, whereas car owners tend to prefer CRHS. Additionally, during rush hours, a strong preference for MRHS emerges, primarily due to shorter waiting times, which underscores MRHS's advantage in high-demand situations. Finally, MRHS users are notably more affected by fare increases than CRHS users, demonstrating greater sensitivity to price changes which could influence their service loyalty.

The heterogeneous nature of commuter travel behavior uncovered in this study necessitates tailored policy measures to optimize the integration of MRHS and CRHS into Hanoi's evolving public transport system. Enhancing MRHS services could significantly alleviate congestion and improve urban mobility, while promoting CRHS might better serve those valuing comfort over cost. These differentiated approaches could lead to a more cohesive and efficient transportation network, fostering a sustainable and commuter-centric urban environment. This research not only deepens the understanding of urban transportation preferences in Hanoi but also offers a solid foundation for policy decisions aimed at enhancing the effectiveness of ride-hailing services within the city's broader transportation framework.

7.2. Recommendations

The study findings could significantly contribute to improving the urban transportation system. To optimize the RHS in Hanoi and enhance overall urban mobility, a comprehensive set of recommendations has been developed based on the study's findings across multiple hypotheses concerning commuter preferences for MRHS and CRHS. Firstly, differential pricing strategies should be considered to reflect the income sensitivity highlighted in Hypothesis 1, offering premium services for higher-income groups and more affordable options for lower-income users. Secondly, initiatives to promote motorcycle-based RHS as a first and last-mile options should be emphasized, aligning with public transport schedules and enhancing connectivity at transit hubs. Thirdly, vehicle transition programs encouraging a shift from personal vehicle use to

RHS could promote environmental and economic benefits, especially enhancing MRHS usage among existing vehicle owners.

Moreover, service availability during peak traffic hours should be optimized to cater to the efficiency of MRHS, as identified in Hypothesis 4, ensuring quick and efficient travel options during high-demand periods. Targeted campaigns and promotional discounts should focus particularly on MRHS users, who are more sensitive to price changes, to maintain and boost ridership effectively. Dedicated infrastructure improvements, such as designated pick-up and drop-off zones for RHS, would reduce traffic disruptions and increase the reliability and speed of service, particularly for MRHS.

Regular assessment of RHS policies and user satisfaction should be implemented to dynamically adapt service offerings and pricing to meet commuter needs and respond to changing urban transport dynamics. Finally, educational campaigns and active community engagement should be conducted to raise awareness about the benefits of RHS, particularly the environmental advantages of MRHS-metro connection over private vehicle use and the cost-benefit comparisons to encourage a broader acceptance and use of these services.

Despite its many potentials, encouraging the use of MRHS requires a well-planned implementation strategy. A high concentration of MRHS in a particular area can increase traffic congestion and destabilize the transportation system. Moreover, uncontrolled MRHS growth can undermine the use of public transportation by offering a more convenient alternative. A feasible solution could be the establishment of designated zones for MRHS. Each MRHS vehicle would be permitted to move only between adjacent zones. This approach could be implemented around metro stations. Consequently, if the travel distance exceeds the distance between MRHS zones, passengers might opt for public transportation.

Considering the current design of metro line 2A stations (Appendix part C), there is no pickup and drop-off zone for taxis and RHS. From the pictures, we could notice MRHS drivers have to pick up and drop off their customers directly on the road or sidewalk at the side or in front of the station exits. This clearly shows that in order to promote MRHS-metro connection effectively and not further complicate the traffic situation around the stations, it is essential to establish pick-up and drop-off zones right from the station design stage.

It can be foreseen that an increase in the use of MRHS, particularly with conventional gasoline-powered motorcycles, may result in higher long-term emissions of pollutants such as CO_2, NOx, and particulate matter. Encouraging or mandating the use of electric motorcycles should be considered to mitigate emissions and reduce environmental impacts. Additionally, motorcycles are not as safe as cars in terms of travel safety, and an increase in MRHS usage can lead to more traffic accidents and fatalities. Therefore, it is essential to establish strict safety and training standards for MRHS drivers, including regular vehicle inspections and mandatory safety courses.

CRHS, while more suitable for door-to-door trips, could also be integrated with public transportation. Policies applied to MRHS could be somewhat adapted for CRHS. For example, establishing pick-up and drop-off points near stations and specific locations such as restaurants, eateries, and pedestrian streets. Additionally, there is an unimplemented method in Vietnam to enhance the use of CRHS, which involves encouraging RHS providers to enable and promote shared ride options. This would make CRHS trips more affordable while still offering the experience of using a car. Furthermore, this approach could reduce the number of vehicles on the road, thereby decreasing traffic congestion and environmental impact.

These recommendations aim to create a more integrated, efficient, and user-centric urban transportation system in Hanoi, leveraging the unique attributes of RHS to enhance commuter experiences and support sustainable urban development. By addressing these specific aspects, policymakers and service providers can ensure that RHS remains a vital component of Hanoi’s transportation landscape, adaptable to the evolving needs of its urban population.

To further specify the necessity of these understandings and recommendations, a summary of RHS in developing countries was conducted. Please refer to Appendix Part D. RHS has confused transportation managers and policymakers since the time of introduction. There are debates about the RHS companies, whether they are transportation or technology companies, as they do business in the transportation field but do not own any vehicles. According to the summary, some countries have been able to legalize the activities of RHS companies. However, the regulations in all countries have stopped there. No further laws or regulations exist to control or integrate RHS use and urban transport development. This situation might result from the lack of research on the impact of RHS on the remaining types of traffic in the market, as pointed out in the literature review. Furthermore, typical challenges and adverse effects across these transport markets are also recognized. Thus, by addressing this gap, this study can contribute to improving the urban transportation system.

7.3. The versatility and transferability of the study.

The versatility and transferability of the findings from this study offer significant value to urban transportation planning and policy development, both within Hanoi and in other urban contexts globally.

The study's methodology, which includes multinomial logit and bivariate probit regression analyses, can be applied to other urban environments to understand the effects of various RHS types on commuter behaviors. This versatility makes it a robust framework for analyzing urban transportation dynamics in different settings. The insights gained from the study can be used to develop targeted transportation policies that address the specific needs and behaviors of RHS users.

The study's findings are transferable to other cities experiencing similar transportation challenges, such as rapid urbanization, high reliance on motorcycles, and emerging RHS markets. Cities in Southeast Asia, Latin America, and Africa, where motorcycles are prevalent and public transport systems are developing, can particularly benefit from these insights. The concept of using MRHS as a feeder mode to metro stations is highly transferable. Other cities with metro systems or those planning to develop such systems could adopt this approach to enhance the accessibility and efficiency of their public transport networks.

While the study is specific to Hanoi, its methodology and key findings can be adapted to local contexts by considering regional variations in transportation infrastructure, cultural attitudes towards different modes of transport, and specific urban mobility challenges. This adaptability ensures that the study's outputs remain relevant across diverse urban environments. The study's insights into the impacts of fare changes on RHS usage can inform the development of dynamic pricing models and regulatory frameworks in other cities. Policymakers can leverage these findings to design fare structures and policies that balance the needs of commuters and RHS providers while promoting sustainable urban mobility.

The study opens avenues for further research on RHS in other developing regions, allowing researchers to build on its findings and explore new dimensions of urban mobility. Comparative studies across different cities can enhance the understanding of RHS's role in global urban transportation systems. However, the specific application of these modes depends on individual cases and may require appropriate adjustments. For example, conducting research on different types of RHS in Thailand would be expected to be more complicated due to the presence of three types of RHS: two-wheel, three-wheel, and four-wheel services. Additionally, the MRT system in Bangkok is quite complete, so the interaction between RHS and public transport there might differ.

Appendix E illustrates a quick comparison between the Association of Southeast Asian Nations (ASEAN) countries to see which country has the most similarities to the findings of this study and to which they can be applied. From the table, most countries share a high percentage of household motorcycle ownership. However, motorcycle usage reflects the diversity of travel choices for people from different countries. Vietnam has fewer transportation choices, so people rely on motorcycles more than Thailand and Indonesia. However, Indonesia is still closer to Vietnam regarding motorcycle utilization than Thailand. This is because car prices in Thailand are very low, and taxes on ownership are also meager, which makes them more reliant on cars. Moreover, according to RHS legalization, the government, Vietnam, and Indonesia treat the RHS similarly. They are recognized as transportation companies (with transport licenses) or technical support companies (without transport licenses). Therefore, Indonesia could be considered the closest country to which the study findings are highly applicable.

In conclusion, the versatility and transferability of this study's outputs make it a valuable resource for urban transportation planners, policymakers, and researchers. By adapting the study's methodology and findings to local contexts, cities worldwide can improve their transportation systems, enhance commuter experiences, and promote sustainable urban mobility.

7.4. Limitations and Future Research Directions

7.4.1. Limitations

This study, while providing valuable insights into commuter preferences for ride-hailing services (RHS) in Hanoi, is not without its limitations. One significant constraint is the static nature of the data used, which captures commuter preferences at a single point in time and may not accurately reflect dynamic changes in these preferences that could occur due to varying economic conditions, evolving urban landscapes, or improvements in public transportation infrastructure. Such static data may lead to an incomplete understanding of the long-term trends and shifts in commuter behavior.

Additionally, the study did not account for external influences that can significantly impact RHS usage. These influences include policy shifts, such as changes in transportation regulation or fare policies, technological advancements that could introduce new mobility solutions or enhance existing ones and shifts in social norms that might influence public perception and acceptance of different transportation modes. For instance, the increasing emphasis on sustainability and environmental concerns could alter public preferences towards more eco-friendly transportation options, potentially skewing the current findings if such trends accelerate.

Furthermore, the impact of external economic factors, such as fluctuations in fuel prices or adoption of electric vehicle, which could affect both the affordability and attractiveness of RHS compared to other transportation modes, was not explored in this study. These factors can play a crucial role in shaping commuter decisions and preferences, particularly in a developing urban context like Hanoi.

7.4.2. Future Research Directions

Given these limitations, future research should consider several avenues to build upon the findings of this study. Longitudinal research is essential to understand how commuter preferences evolve over time in response to internal and external changes. Such research could track the impacts of specific policy changes, economic shifts, and technological advancements on RHS usage patterns.

In addition, there is a need to examine the effects of emerging transportation technologies, such as autonomous vehicles and electric scooters, on RHS markets. These technologies promise to reshape urban transport landscapes dramatically, and understanding their potential impact on traditional RHS models will be crucial for adapting business strategies and regulatory frameworks.

Finally, it would be beneficial for future research to incorporate a broader range of demographic factors and personal characteristics, such as environmental consciousness, openness to technology, and lifestyle choices, which could influence the preference for and usage of RHS. This would enable a more nuanced understanding of the drivers behind RHS preferences and help tailor services to meet diverse commuter needs more effectively.

By addressing these limitations and exploring these suggested directions, future research can provide deeper insights into the complexities of urban mobility and the role of RHS within it, facilitating more informed and effective transportation policy and planning decisions.

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Appendixes

Appendix A: Survey questionnaire form

No. ___________

Questionnaire about Commuter Travel Behaviors in Hanoi

The purpose of this questionnaire is to examine the travel behavior of passengers in the urban traffic environment in Hanoi. Your responses will be anonymous, and the information answered here, other than for scientific research, will not be used for any other purpose. We look forward to receiving your cooperation and very sorry for the inconvenience!

YNU 横浜国立大学 YOKOHAMA National University
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TRƯỜNG ĐẠI HỌC GIAO THÔNG VẬN TẢI
UNIVERSITY OF TRANSPORT AND COMMUNICATIONS

Questionnaire interviewer team is composed of **University of Transport and Communications**

Please write a number inside(________). ex：(___3___)
Please write an answer inside 【　　　　　　】

For interviewer only

Date：(______)/March/2023	Finished time：☐AM ☐PM(_______)h(________)m
Weather：☐Sunny ☐Cloudy ☐Rain	Interviewer Name：___________________

PART 1：Personal Information.

Q1. Your Gender (single answer)	☐Male ☐Female
Q2. Your Age (single answer)	☐<18 ☐18-23 ☐23-40 ☐40-60 ☐>60
Q3. Education Level (single answer)	☐Below High School Level ☐High School Level ☐College ☐Undergraduate ☐Graduate ☐Others【 】
Q4. Occupation (single answer)	☐Student ☐Office Staff ☐Freelancer ☐Housewife ☐Service Industry Worker ☐Government Officer ☐Unemployed/Retired ☐Others【 】
Q5. Total monthly income (single answer)	☐≤ 5,000,000VNĐ ☐From 5,000,000VNĐ to≤ 8,000,000VNĐ ☐From 8,000,000VNĐ to ≤ 12,000,000VNĐ ☐From 12,000,000VNĐ to ≤ 20,000,000VNĐ ☐≥ 20,000,000VNĐ
Q6. Your marital status (single answer)	☐Single ☐Married ☐Divorced ☐Others【 】
Q7. How many of the following vehicles does you own?	Bike (_______) Electric Bike (_______) Motorbike (_______) Car (_______)
Q8. If you do not have a car, do you have plans to buy it in the future?	☐No ☐Yes, in about under 3 years ☐Yes, in about 3-5 years ☐Yes, in about more than 5 years
Q9. Your current home address? *(Please be as specific as you could)*	Street ____________ Ward____________ District______________
Q10. What is your current residency?	☐Owner ☐Live with parents ☐Rent
Q11. Your current study/work address *(Please be as specific as you could)*	Street ____________ Ward____________ District______________

PART 2：Information about daily commute.

Q12. What is your daily main mode of transport? (The vehicle that you use for the longest distance traveled in your total trip) (single answer)	☐Walking ☐Bike ☐Electric bike ☐Motorbike ☐Traditional motorbike taxi ☐Motorbike-based RHS ☐Car ☐Taxi ☐Car-based RHS ☐Bus/BRT ☐Metro train ☐Others【 】
Q13. What is the most important factor leading you to choose your main means of travel? *(Up to 3 options can be selected)*	☐Travel time ☐Travel cost ☐Travel Safety ☐Healthy ☐Eco-friendly ☐Comfortable ☐Convenient, actively travel ☐Door-to-door access ☐No need to travel with others ☐No need waiting time ☐Personal Safety ☐Have seat ☐Punctual ☐No other option to choose ☐Others【 】
Q14. If the main means of transport in Q12 is Bus, BRT, MRT, what means of transport do you often use to get to the bus station/train station?	☐Walking ☐Motorbike ☐ Car ☐Motorbike-based RHS ☐Car-based RHS ☐Others【 】
Q15. If your main means of transport in Q12 is RHS, BRT, MRT, please indicate the previous main means of transportation that you used when the above vehicles were not available	【 】

Q16. How much time do you usually spend commuting from home to your work/study?	(_______)hours (_______)minutes
Q17. How far is your daily commute from home to work/study?	(_______)km
Q18. Please indicate the order of your daily trips and the means you use for each trip. For example: - First: To work - Bus - 2nd: To eat - Walking - 3rd: To go out - Motorbike-based RHS - Final: Go home - Motorbike-based RHS	- First:_______________ - 2nd:_______________ - 3rd:_______________ - Final:_______________ *(Please use the blank space if there are more trips)*
Q19. What is your travel cost for your daily trip by main vehicles (one time going from home to work/study or vice versa)?	(_______)VNĐ
Q20. Does your workplace or study have a parking lot?	☐Yes ☐No
Q21. Do you have to pay monthly expenses for parking at your workplace or study?	☐Yes (_______)VNĐ/month ☐No

PART 3：Evaluation of using Ride-hailing Service

Q22. What type of RHS do you often use? (single answer)	☐Motorcycle-based RHS ☐Car-based RHS ☐Both RHS
Q23a. How often do you use Motorcycle-based Ride-Hailing Service? (single answer)	☐Rarely ☐Less than 1 time/week ☐2-3 times/week ☐4-5 times/week ☐6-7 times/week ☐More than 7 times/week
Q23b. How often do you use Car-based Ride-Hailing Service? (single answer)	☐Rarely ☐Less than 1 time/week ☐2-3 times/week ☐4-5 times/week ☐6-7 times/week ☐More than 7 times/week
Q24a. What is the common purpose of your trip using motorcycle- based RHS? (multiple answer)	☐Go to workplace/ school ☐Visit relatives, friends ☐Go shopping, buying groceries ☐Go to eat, drink ☐Pick up, drop off ☐Go out, go to events ☐Connect with bus, metro train ☐Go home
Q24b. What is the common purpose of your trip using car- based RHS? (multiple answer)	☐Go to workplace/ school ☐Visit relatives, friends ☐Go shopping, buying groceries ☐Go to eat, drink ☐Pick up, drop off ☐Go out, go to events ☐Connect with bus, metro train ☐Go home
Q25. Which RHS provider that you often use? (multiple answer allowed)	☐Grab ☐GoJek ☐Be ☐MyGo ☐Others【 】
Q26. What made you choose the above provider to use RHS rather than others? (Up to 3 answers)	☐Better fare ☐Better service ☐Short waiting time ☐Due to familiar use ☐More preferential ☐Others【 】

Q27. If you use both types of RHS but from different providers, please indicate the reason. (Skip if using same provider) (Up to 3 answers)	☐Availability ☐Cost ☐Personal preference ☐Service experience ☐Service quality consistency ☐Others【 】				
Q28. How long is your average waiting time to use RHS?	Motorcycle-based RHS(_______)minutes Car-based RHS(_______)minutes				
Q29. How far is the travel distance that you usually use RHS for?	Motorcycle-based RHS(_______)km Car-based RHS(_______)km				
Q30. How long is the travel time for the above-mentioned distance using RHS?	Motorcycle-based RHS(_______)minutes Car-based RHS(_______)minutes				
Q31. What is your travel cost for your typical trip using RHS?	(_______)VNĐ				
Q32. If you have to use RHS during the rush hour, which options do you prefer?	☐Motorcycle-based RHS ☐Car-based RHS ☐Taxi ☐Waving for Taxi/RHS				
Q33. Which is the main reason for your choice in Q.32? (Up to 3 answers)	☐Time ☐Cost ☐Convenience ☐Accessibility ☐Availability ☐Others【 】				
Q34. If you've used Grab, the fare has increased several times with the latest in 10/3/2022. Has that had any effect on your use? (single answer)	☐Reduction on frequency of use ☐Switch to lower-cost options ☐Use only when necessary ☐No effect at all, still use as normal ☐Others【 】				
Q35. If the cost of using RHS becomes 15% higher in the future, which mode would you consider for trips currently using RHS? (single answer)	☐Keep using ☐Switch to walking ☐Switch to public transport ☐Switch to motorbike/car ☐Switch to bike/electric bike ☐Others【 】				
Q36. How would you rate the use of RHS compared to the use of personal vehicle.	Strongly agree	Agree	Neutral	Disagree	Strongly Disagree
Faster travel time					
Lower travel cost					
Safer in avoiding traffic accidents (after drinking)					
Safer from being robbed					
Safer in evening/night commuting					
More convenient					
More actively					
Limit stress while driving					
Less traffic congestion					
Little distinction between rich and poor					

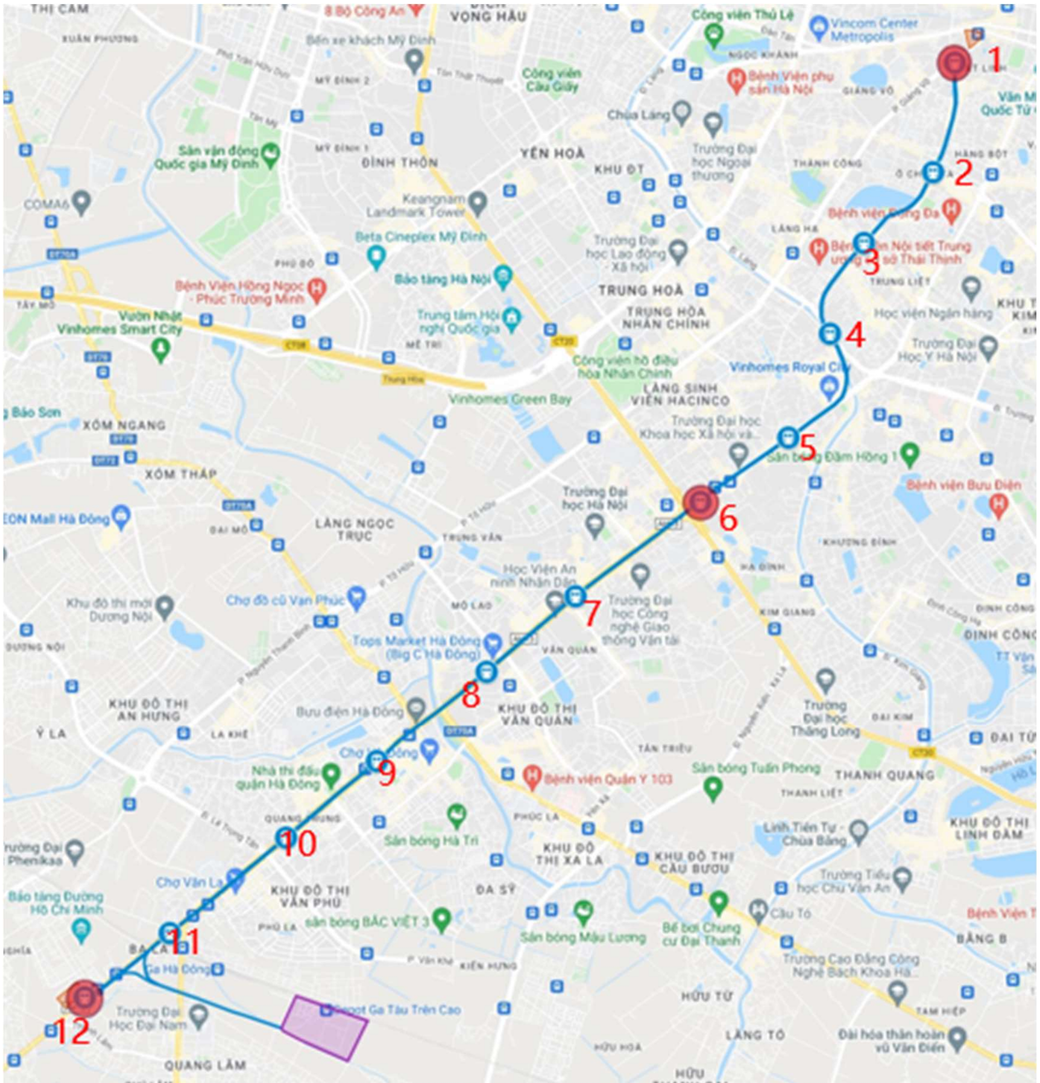
PART 4：Evaluation of using Urban Railway Line 2A Cat Linh – Ha Dong of Hanoi City.

Q37. Have you ever used Metro Line 2A?	☐Yes ☐No		
Q38. If the answer of Q37 is Yes, please indicate how often you use the Metro Line 2A. (single answer)	☐Daily ☐Few times a week ☐Rarely ☐Others【 】		
Q39. Based on your experience and perception about Metro line 2A and Bus/BRT, which is better in term of:	Please tick the mode that you think is better based on the comparison criteria		
Acceptable time travel	☐ Metro	☐ Same	☐ Bus/BRT
Acceptable punctuality	☐ Metro	☐ Same	☐ Bus/BRT
Good security level	☐ Metro	☐ Same	☐ Bus/BRT
Good travel safety level	☐ Metro	☐ Same	☐ Bus/BRT
Comfortable when travel	☐ Metro	☐ Same	☐ Bus/BRT
Avoid peak hours	☐ Metro	☐ Same	☐ Bus/BRT
Satisfaction level	☐ Metro	☐ Same	☐ Bus/BRT
In hurry to catch a trip	☐ Metro	☐ Same	☐ Bus/BRT
Q40. For the quality of current MRT service (punctuality, comfort ...), would you be able to walk longer distances than using conventional BUS/BRT?	☐Yes ☐No		
Q41. When using public transport, what is your maximum acceptable walking distance to the station (where 400m walk equals 5 minutes):	- Bus/BRT (________)m - Metro train (________)m		
Q42. In the future, if there is a metro line that is suitable or close to your daily destination, would you consider using it?	☐Yes ☐No		
Q43. If the metro station is further than your acceptable walking distance, what transport would you use to get to that metro station to catch the train? (single answer)	☐Bike ☐Electric bike ☐Motorbike ☐Car ☐Motorcycle- based RHS ☐Car-based RHS ☐Taxi ☐Bus		

This is the end of the questionnaire. Thank you for your cooperation.

Appendix B: Questionnaire survey photos

Appendix C: Photos of current Metro Line 2A stations.



Metro line 2A, the first metro line in Hanoi

Cat Linh Station (Station 1) Main exit

Cat Linh Station (Station 1) Side exit

Yen Nghia Station (Station 12) Main exit

Yen Nghia Station (Station 12) Side exit

Appendix D: Summarize Table of Ride Hailing Services in Developing Countries

RHS Market	Key players	Original Country	Years of Operation	Type of services	Selling points/ Remarks	Market Share	Regulated ?	Market Challenges
Kigali, Rwanda (2 RHS providers)	VWMove	Rwanda	2019	CRHS	- **All vehicles are Volkswagen cars** - Requires a local SIM to activate	In Kigali (2022): Yego 3000 veh Move 150 veh	Not fully (Only required usage of meters)	- Drivers not used to the apps and ring the user to confirm location - **Many trips still happen off the meter** - ETA is not accurate and it takes lots of patience which could outweigh the convenience.
	Yego	Rwanda	2018	MRHS CRHS	**Can call 9191 to order rides**			
Nairobi, Kenya (Around 16 RHS providers)	Uber	USA	2015	MRHS CRHS car-sharing	- Well-known brand - Mapping technology ensures quickest route	- CRHS: Uber (69%), Bolt (21%), Little Cab (10%) - Car-sharing: Uber (48%), Bolt (30%), Little Cab (22%) - MRHS: Safe boda (52%), Bolt (27%), Uber (14%), Little Cab (7%)	Not fully (Only required share drivers & rider's data. Failed to require obtaining a transport network license & capping the service fee)	- **Uncontrolled growth** of RHs drivers in Nairobi (environment problem, traffic congestion…) - RHS companies have no responsibility for their drivers by labelling themselves as tech companies and drivers as independent contractors
	Bolt (Taxify)	Estonia	2016	MRHS CRHS car-sharing	- **Loyalty program** to redeem discounts for future rides			
	Little Cab	Kenya	2016	MRHS CRHS car-sharing	- Allow **non smartphone users** to hail taxis **via SMS** - Lower commission than other brands			

RHS Market	Key players	Original Country	Years of Operation	Type of services	Selling points/ Remarks	Market Share	Regulated ?	Market Challenges
Kathmandu, Nepal (Over 35 RHS providers in last 7 years, many of them stop operation)	Tootle	Nepal	2017	MRHS CRHS	- Lost market share and stopped service in 2022 but returned in Sep 2023 - Have insurance for riders and users, temporary no commission on rides	In 2022, Pathao (47%), InDrive (31%), Tootle (14%) Others (8%)	Fully (Include RHS as service-oriented industry in Feb 2024)	- **Lack of regulation.** RHS drivers got fined for using private vehicles for public transport purposes. RHS companies did not register activities or pay taxes (Solved with new regulation in Feb 2024) - A surge in **offline RH to avoid commissions**. The ride will not be recorded and have safety problem.
	InDrive	USA	2022	MRHS CRHS	- Popular for **allowing users to bargain the price** with drivers on the apps - **Official launched in May 2024** by following the new regulation of Nepali government. (0% commission =>10%)			
	Pathao	Banglades h	2018	MRHS CRHS 3-wheelers RHS	- Pathao has become famous for offering various services rather than just RHS - First company to introduce insurance services to both riders and users			

RHS Market	Key players	Original Country	Years of Operation	Type of services	Selling points/ Remarks	Market Share	Regulated ?	Market Challenges
Manila, Philippines (various of RHS providers)	Grab	Singapore	2013	MRHS CRHS	- Extends far beyond just taxi services, offering a diverse array of options - Well-known for large groups of drivers that available almost any area, reasonable price and good customer service	Lack of market share report Based on number of downloads of RH Apps in 2022: Grab > 100 mil Angkas > 1 mil JoyRide > 100k (Notes: All numbers of downloads are worldwide, but Grab operates in many countries in SEA region. Angkas and JoyRide are operating in Philippines only	Fully RHS providers as transport network company (TNC) RHS as Transport Network Vehicle Services (TNVS)	- **Regulatory hurdles**: varying rules across regions -**Infrastructure Limitation**: Inadequate Road infrastructure can limit the efficiency of these services. - **Market Saturation**: With many players in the market, maintaining a competitive edge becomes increasingly difficult.
	Angkas	Philippines	2016	MRHS	- Offers affordable prices compared with traditional taxis for short to medium-distance travel - Huge number of drivers and quick response time			
	Joyride	Philippines	2019	MRHS CRHS	- Have an option for regular metered taxi RHS - Smaller player in the market, not as widespread as Grab or Angkas			

<table>
<tr><th>RHS Market</th><th>Key players</th><th>Original Country</th><th>Years of Operation</th><th>Type of services</th><th>Selling points/ Remarks</th><th>Market Share</th><th>Regulated ?</th><th>Market Challenges</th></tr>
<tr><td rowspan="4">Bangkok, Thailand

(various of RHS providers)</td><td>Grab</td><td>Singapore</td><td>2013</td><td>MRHS
CRHS</td><td>- Offers many promotions and discounts to users, making it affordable.

- Dominates the market</td><td rowspan="4">- In 2022,
By volume order
Grab 72% ,
Bolt 28%

By sales
Grab 80%,
Bolt 20%

- In 2023,
By revenue (mil bath)

Grab 15197
profit 576

Lineman 7803
lost 2731

Robinhood 538
lost 1987</td><td rowspan="4">Not fully

(CRHS is legally recognized by the regulatory framework but MRHS is not)</td><td rowspan="4">-Regulatory hurdles, licensing requirements, and compliance with local laws.

- Safety concerns, such as driver background checks, passenger privacy, and security during rides.

- The profitability of Ride-Hailing companies is not that good leading to potential financial instability.</td></tr>
<tr><td>Lineman</td><td>Thailand</td><td>2018</td><td>MRHS
CRHS</td><td>- Launched with support from Thai government

- Have partnership with biggest taxi association in Bangkok

- Leading in food delivery section</td></tr>
<tr><td>Robinhood</td><td>Thailand</td><td>2020</td><td>MRHS
CRHS</td><td>- Expanded business from delivery service to RHS

- Suffer financial problem and will cease operation on 31st July 2024</td></tr>
<tr><td>Bolt</td><td>Estonia</td><td>2020</td><td>MRHS
CRHS</td><td>- Referred as lower price RH company

- Only operates in Thai in SEA region</td></tr>
</table>

RHS Market	Key players	Original Country	Years of Operation	Type of services	Selling points/ Remarks	Market Share	Regulated ?	Market Challenges
Hanoi, Vietnam (more than 10 RHS providers)	Grab	Singapore	2014	MRHS CRHS	- Won and acquired Uber's facility in the SEA region - Accumulated **4300 billion** VND losses (2021)	58.68%	Fully (RHS companies must register as Transport business services or transport connection support services)	- **Intense competition** in the context of **reducing the financial deficit** - **Regulatory hurdles** - Concerns over driver and passenger safety .
	XanhSM	Vietnam	**2023**	MRHS CRHS	- **Fully electric vehicle, owned by company** not drivers - **Employs driver directly**	**18.17%**		
	Be	Vietnam	2019	MRHS CRHS	- Self-claimed to broke even after two years - Multi-service: RHS, delivery, air ticket purchases, insurance, …	9.21%		
	Gojek	Indonesia	2018	MRHS CRHS	- Promotions such as flat trip prices of 1000 and 5000VND, and no commission for drivers. - Accumulated **4000 billion** VND losses (2021)	5.87%		

As for Latin America countries, the market is very interconnected and competitive for the RHS. Most RHS companies run their service across the region. The top competitors are Didi Chuxing, Uber, Easy Taxi, Cabify, 99, Beat, and InDrive. It should be noted that all these companies only provide CRHS. Picap is the only company offering the MRHS. However, they are operating in countries throughout the region: Colombia, Mexico, Guatemala, Nicaragua, Paraguay, Argentina, Chile, Brazil, Ecuador, Dominican Republic and Costa Rica. It is interesting to see that such a potential market is currently being exploited by just one company.

Regarding the regulation, Brazil, Mexico, and the US have had Ride-Hailing regulations for some time while Chile has published a new Ride-Hailing law this year. Colombia and Argentina don’t have specific Ride-Hailing regulations at this point.

Appendix E: Comparison between some ASEAN countries

RHS Market	Household's Motorcycle Ownership*	Motorcycle Usage**	RHS Legalization***
Philippines	32%	6.6%	Fully - RHS providers as transport network company and RHS as Transport Network Vehicle Services
Thailand	87%	30.6%	Not fully - CRHS is legally recognized by the regulatory framework, but MRHS is not
Vietnam	86%	72.8%	Fully - RHS providers as Transport business services or Transport connection support services
Indonesia	85%	45.1%	Fully – RHS providers as "apps companies" and required to partner with transportation companies licensed by the ministry or compelled to register for their own transportation company license
Malaysia	83%	45.2%	Fully - Intermediation business license is required for RHS providers, but MRHS is banned

* World Atlas Report "Countries with the Highest Motorbike Usage" - 2019

**Seasia Report "Percentage of Motorbike Usage in Southeast Asia" - 2023

*** "Regulating App-based Mobility Services in ASEAN", International Transport Forum Policy Papers, No. 112 OECD Publishing, Paris. - 2023

Appendix F: Program Codes

1. Bivariate Binary Probit Regression Model – For Hypothesis 1&2

1.1. STATA (used to present as final result)

```
* Load the data set

import excel "D:\DataFinal.xlsx", sheet("Data") firstrow



* Perform the Bivariate Probit Regression with all predictors

biprobit MRHS CRHS Age Gender Education Income Ownership RHSConnect



* Store the log-likelihood and the number of parameters for the full model

local log_lik_full = e(ll)

local num_params = e(df_m)



* Calculate AIC for the full model

local aic = 2 * `num_params' - 2 * `log_lik_full'

display "AIC (Full Model): " `aic'



* Fit the null model with only intercepts

biprobit MRHS CRHS
```

```
* Store the log-likelihood of the null model

local log_lik_null = e(ll)


* Calculate McFadden's Pseudo R-squared

local pseudo_R2 = 1 - (`log_lik_full' / `log_lik_null')

display "McFadden's Pseudo R-squared: " `pseudo_R2'


*Calculate Variance-inflation factor (VIF)

collin Gender Age Income Education Ownership RHSConnect if e(sample)
```

1.2. R Program (used to compare the results of the first program)

(This analysis uses the mvProbit package.)

 --- Model Estimation ---

```
# Install and load the required packages

install.packages("mvProbit")

install.packages("readxl")

library(mvProbit)

library(readxl)

# Load the dataset from the Excel file
```

```r
data <- read_excel("D:/DataFinal.xlsx", sheet = "Data")

# Estimate the Bivariate Binary Probit model

biv_probit_model <- mvProbit(cbind(MRHS, CRHS) ~ Gender + Age + Education + Income + Ownership + RHSConnect, data = data, iterlim = 10, nGHK = 50)

# Display the summary of the model

summary(biv_probit_model)
```

- --- Pseudo R-Square Calculation (McFadden's R-Square) ---

```r
# Calculate the log-likelihood of the model

logLik_model <- logLik(biv_probit_model)

# Calculate the log-likelihood of a model with no predictors

# For the null model, we'll use only the intercept (no predictors) in a combined formula

null_model <- mvProbit(cbind(MRHS, CRHS) ~ 1, data = data, iterlim = 10, nGHK = 50)

logLik_null <- logLik(null_model)

# Calculate McFadden's R-Square

pseudo_R2 <- 1 - as.numeric(logLik_model) / as.numeric(logLik_null)

# Print McFadden's R-Square

cat("McFadden's Pseudo R-Square:", pseudo_R2, "\n")
```

--- Akaike Information Criterion (AIC) Calculation---

```
# Extract the log-likelihood of the model

log_likelihood <- logLik(biv_probit_model)

# Count the number of parameters in the model

num_parameters <- length(coef(biv_probit_model))


# Calculate the AIC

aic_value <- 2 * num_parameters - 2 * as.numeric(log_likelihood)

# Print the AIC value

cat("AIC value:", aic_value, "\n")
```

2. Seemingly Unrelated Bivariate Ordered Probit Regression Model– For Hypothesis 3

This part was only done with STATA because analysis Bivariate Ordered Probit Regression using R is complicated, let alone Seemingly Unrelated Bivariate Ordered Probit Regression which is even more complexed.

```
global y1list FreqM

global y2list FreqC
```

```
global xlist Gender Age Income Education OwnershipM

global zlist Gender Age Income Education OwnershipC


describe $y1list $y2list $xlist

summarize $y1list $y2list $xlist


tabulate $y1list $y2list

correlate $y1list $y2list


* Run the Seemingly Unrelated Bivariate Ordered Probit regression

bioprobit ($y1list = $xlist) ($y2list = $zlist)


*Call the AIC value

estat ic


* Store the log-likelihood of the fitted model

local ll_fitted = e(ll)


* Run separate null models for each outcome variable
```

```
oprobit $y1list

local ll_null_y1 = e(ll)


oprobit $y2list

local ll_null_y2 = e(ll)


* Calculate the total log-likelihood of the null model (sum of the individual log-likelihoods)

local ll_null = `ll_null_y1' + `ll_null_y2'


* Calculate and display the Pseudo R-squared

display "Pseudo R-squared = " 1 - (`ll_fitted' / `ll_null')


*Calculate Variance-inflation factor (VIF)

collin Gender Age Income Education OwnershipM OwnershipC if e(sample)
```

3. Multinomial Logit Regression Model – For Hypothesis 4

3.1. STATA (used to present as final result)

```
* Load the data set

import excel "D: \DataFinal.xlsx", sheet("Data") firstrow
```

* Perform the Multinomial Logit Regression with all predictors

mlogit ModeRushHour Age Gender Education Income MRHSxWTMC CRHSxWTCar RConve RAccess RAvail

* Call the AIC value

estat ic

*Calculate Variance-inflation factor (VIF)

collin Gender Age Income Education MRHSxWTMC CRHSxWTCar RAvail RConve RAccess if e(sample)

(Pseudo R-squared is already indicated in mlogit function so don’t have to call or calculate it with code)

3.2. R Program (used to compare the results of the first program)

 --- Model Estimation ---

Install and load the necessary package

install.packages("nnet")

```
library(nnet)

install.packages("readxl")  #(only if not install in Part 1.2)

library(readxl)


# Load the dataset from the Excel file

data <- read_excel("D:/DataFinal.xlsx", sheet = "Data")


# Estimate the Multinomial Logit model

model <- multinom( ModeRushHour ~ Gender + Age + Education + Income +
MRHSxWTMC + CRHSxWTCar + RConve + RAccess + RAvail, data = data)

# Display the summary of the model

summary(model)
```

(There is already AIC in the summary so no need to use code to indicate it)

- --- Hit Ratio Calculation ---

```
# Calculate predicted probabilities

predicted_probs <- predict(model, type = "probs")

head(predicted_probs)


# Predict the class labels
```

```
predicted_classes <- predict(model, type = "class")

head(predicted_classes)


# Calculate the hit ratio

hit_ratio <- mean(predicted_classes == data$ModeRushHour)

cat("Hit Ratio:", hit_ratio, "\n")


	--- McFadden's Pseudo R-squared Calculation  ---

# Log-likelihood of the fitted model

logLik_model <- logLik(model)


# Log-likelihood of the null model (only intercept)

null_model <- multinom(ModeRushHour ~ 1, data = data)

logLik_null <- logLik(null_model)


# McFadden's Pseudo R-squared

pseudo_R2 <- 1 - as.numeric(logLik_model) / as.numeric(logLik_null)

cat("McFadden's Pseudo R-squared:", pseudo_R2, "\n")
```

Note: For Hypothesis 5, Logistic Regression Model and Bivariate Binary Probit Regression Model are used.

- Logistic Regression : simple to code

STATA code: logistic FareInc Gender Age Education Income Ownership TravelCost TToTDMC TToTDCar, vce(cluster Mode)

- Bivariate Binary Probit Regression Model : please refer to Part 1, do the same as for Hypothesis 1&2