



Car versus motorcycle ride-hailing applications: User behaviors and adoption factors in Bangkok, Thailand

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ABSTRACT

Ride-hailing applications (RHA) have surged in popularity in Southeast Asia, yet research comparing car and motorcycle RHA user characteristics, trip behaviors, and factors influencing adoption remain limited. To fill this gap, this study investigated motorcycle RHA use individually and in conjunction with use of car RHA by using the bivariate probit regression to analyze traveler intercept survey data from Bangkok, Thailand. Our findings revealed that car RHA has a higher market penetration rate than motorcycle RHA but that motorcycle RHA is used more frequently. Motorcycle RHA was adopted and used more frequently by individuals who have access to a private car and reside in areas with high urban rail accessibility. Notably, motorcycle RHA was used to connect to urban rail significantly more than car RHA, illustrating the need for policies that facilitate the connective role of motorcycle RHA in accessing public transportation. Overall, our results support the synergy hypothesis between car and motorcycle RHA based on the highly significant correlation between the two modes in the bivariate probit models.

1. Introduction

Ride-hailing applications (RHAs) are online smartphone platforms that provide on-demand ride-hailing services. The first RHA emerged in 2009 (Clewlow and Mishra, 2017). In 2018, the global market value of RHA reached \$174.8 billion, covering more than 2,600 cities in 85 countries (Brail, 2020). The market valuation and penetration of RHA continues to grow, making it essential to understand how RHA interacts with existing transportation infrastructure and urban planning policy. RHAs have previously been analyzed according to user characteristics, user behaviors, and trip characteristics, as well as discussed in relation to their impacts on travel behavior, existing public transport, and society (Chalermpong et al., 2022; Lavieri and Bhat, 2019; Tang et al., 2019; Tirachini, 2019; Young and Farber, 2019; Clewlow and Mishra, 2017).

To date most studies on RHAs have focused squarely on car RHAs and were based on research in Western countries and China (Tirachini, 2019). This is understandable given that more than 70 % of the RHA market valuation is attributed to Uber and Didi-Chuxing, two car RHAs

headquartered in the United States and China (Brail, 2020; Didi, 2021; Uber, 2021). However, in Southeast Asia the transportation landscape looks radically different as motorcycle RHAs have soared in popularity and market value (Wadud, 2020). Gojek, an Indonesian-based motorcycle RHA firm, became a unicorn in 2016 (Brail, 2020) and Grab, a unicorn with world's fourth highest and Southeast Asia's highest market valuation (Brail, 2020), has a major presence in the Indonesian, Thai, and Vietnamese motorcycle RHA markets (Grab, 2021).

In Southeast Asia motorcycles have an advantage over cars in terms of faster travel time in congested traffic as motorcycles can weave paths around cars. However, the unique characteristics reflected in different use behaviors of motorcycle and car RHAs may suggest a possible synergistic relationship between these two modes rather than a competing relationship. Notably, users of both modes shared some common characteristics, namely higher adoption rates among younger and higher-educated individuals (Kong et al., 2020; Rizki et al., 2021; Tirachini, 2019) and some RHAs in Southeast Asia integrate both car and motorcycle services within their apps.

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Still, differences in trip purpose and frequency in car versus motorcycle RHA usage have been documented in the region. More than 30 % of motorcycle RHA trips were used for work or business (Irawan et al., 2020b; Suatmadi et al., 2019; Wicaksono et al., 2017), while leisure trips were the most common trip purpose for car RHA (Tirachini, 2019). In addition, motorcycle RHAs were used more frequently at more than six times per month (Suatmadi et al., 2019; Wicaksono et al., 2017) compared to just a few times per month for car RHAs (Tirachini, 2019). Moreover, motorcycle RHAs were found to support connection to existing public transport (Irawan et al., 2020b), while car RHAs were found to substitute public transportation (Tirachini, 2019).

The emergence of RHA has allowed travelers to access and easily compare multiple travel mode choices (e.g., car, motorcycle) so they can select the most appropriate travel mode according to the specific needs of any given trip. Understanding travel behaviors of RHA users is a necessary foundation for creating policies that aim to address any adverse impacts of RHA while also improving the transportation infrastructure and system in order to maximize potential benefits of RHA. To the authors' knowledge, past research tended to focus on each mode of RHA separately (Alemi et al., 2019; Clewlow and Mishra, 2017; Kong et al., 2020; Suatmadi et al., 2019; Teo et al., 2018) or in conjunction with other non-RHA modes (Irawan et al., 2020a,b; Nistal and Regidor, 2016; Paronda et al., 2016; Contreras and Paz, 2018; Irawan et al., 2022), and no previous research investigated how RHA users select between car and motorcycle services simultaneously. Our study aims to provide context on car and motorcycle RHA usage and behavior in Bangkok, Thailand in order to complement this growing body of research and draw out policy recommendations for transport planners within government and the private sector. Motorcycle RHA services remain largely demand-driven in Bangkok, allowing us to see the operation of RHAs without significant government regulation. Note that the scope of this research is on the demand for online application-based ride-hailing services, but not any other ride-hailing platforms provided by transportation operators.

The remainder of this paper is organized as follows. A review of the literature on motorcycle-based RHA is provided in the next section. The study area, data collection methodology, and modeling methodology are explained in section 3. Descriptive and modeling results are presented in section 4 and discussed in section 5. Finally, we offer policy recommendations on the relationship between RHAs and public transportation based on our findings in section 6.

2. Literature review

The majority of existing literature on RHAs focuses on Western markets. In particular, user characteristics, trip characteristics, and impacts of car RHAs in Western countries have been comprehensively reviewed (Tirachini, 2019). Yet given the differences with Asian markets — namely motorcycle RHA options, transportation infrastructure, and economic contexts — we will focus on research conducted on car and motorcycle RHAs in developing middle-income countries in Southeast Asia — Malaysia, Indonesia, and the Philippines. Furthermore, most of the studies from Southeast Asia have explored RHA use behavior and loyalty to RHA companies, collecting data only from RHA users. Accordingly, our research aims to fill this gap by incorporating behavior analysis of both those who use and do not use RHA.

In terms of user demographics, key studies on car RHA users in Asia found that most users are young individuals, mirroring findings from Western studies (Irawan et al., 2022; Laosinwattana et al., 2023; Nguyen-Phuoc et al., 2020b; Nistal and Regidor, 2016; Thaitatkul et al., 2021, 2023; Weng et al., 2017). Adoption was also skewed by gender; the proportion of car RHA users was found to be more female than male in Manila and Kuala Lumpur, suggesting that RHA helps address women's mobility needs (Nguyen-Phuoc et al., 2020b; Weng et al., 2017). We therefore hypothesized that car RHA users are young (H1) and female (H2).

Two main variables analyzed in previous research included the effect of car ownership on RHA adoption and usage in regards to access to public transportation. Notably, the effect of vehicle ownership on car RHA adoption has mixed results depending on the country. One study out of Manila in the Philippines discovered that most car RHA users owned a private car (Nistal and Regidor, 2016), but this differs from research in Vietnam that found most of car RHA users (>70 %) do not own a car (Nguyen-Phuoc et al., 2020b). In relation to public transit, in Western studies car RHAs were used to replace 'competing' modes of transportation — chiefly taxis and public transport (Tirachini, 2019). Research from Tirachini and del Río (2019) in Chile showed that 65 % of car RHA users mentioned that their main mode of transport was public transit. Furthermore, they found that 96 % of car RHA users did not use RHA in combination with another transportation mode, such as connecting to public transit. This may be because car RHAs were only used occasionally and mostly for leisure trips within cities (Tirachini, 2019; Tirachini and del Río, 2019). We thus hypothesized that car RHA users are taxi users (H3) and public transport users (H4). Furthermore, we hypothesized that car RHA is not used for commuting, but rather for leisure trips (H5).

Infrastructure in an individual's area of residence also played a significant role in RHA use. In the United States, car RHA was used by individuals who live in mixed land use areas where land is used for residential, business, green space, and shopping purposes (Alemi et al., 2018). In Bangkok mixed land use areas are largely in urban areas with multiple public transport options. Accordingly, we hypothesized that car RHA users reside in these areas (H6) and have many travel options (H7).

While these car RHA studies provide insight into user demographics, trip purpose, and residential environments, studies on the demand of motorcycle RHA are relatively limited. We therefore developed the hypotheses based on studies of motorcycle RHA and conventional motorcycle taxis. Regarding the sociodemographic determinants of motorcycle RHA adoption, previous studies on motorcycle RHAs and motorcycle taxis in Indonesia and Vietnam found that motorcycle RHA users are primarily young female individuals (Silalahi et al., 2017; Suatmadi et al., 2019; Tuan and Mateo-babiano, 2013). In addition, 72 % of motorcycle RHA users in Indonesia were found to have access to a private vehicle, be it a personal motorcycle or car (Suatmadi et al., 2019). Given these findings, we hypothesized that motorcycle RHA users are young (H8) female (H9) individuals who have access to a private vehicle (H10).

Based on the previous car RHA hypothesis, motorcycle RHAs might serve as a substitute to conventional motorcycle taxis, which need to be flagged down on public street corners. We therefore hypothesized that motorcycle RHA users are individuals who generally travel by conventional motorcycle taxis (H11). Furthermore, we hypothesized that motorcycle RHA is used as a means of connecting to public transportation (H12). According to the studies of (Phun et al., 2019) and (Ratanawaraha and Chalermpong, 2015), densities of motorcycle taxis within a one kilometer circumference of transit stations have substantially increased in recent years. Accordingly, we also hypothesized that motorcycle RHA is used in areas with urban train stations — subways and conventional rail — (H13) and by individuals who have many travel options (H14). Lastly, we hypothesized that motorcycle RHAs are used quite frequently (H15). According to previous studies from Indonesia, over 50 % of motorcycle RHA users use this service more than five times a week (Silalahi et al., 2017; Suatmadi et al., 2019). Because of the high frequency of use, we further hypothesized that motorcycle RHA is used for commuting, rather than for leisure (H16).

3. Methodology

3.1. Study area

Our research focused on Bangkok, which has a total land area of 1600 sq.km with a 5.59 million registered population as of December

2020 (The Bureau of Registration Administration, 2021). Bangkok, the capital of Thailand, is the largest metropolis with its Gross Provincial Product at 5.71 million THB, which accounted for 33.79 % of Gross Domestic Product in 2019 (Office of the national economic and social development council, 2019). The average household monthly income in Bangkok is 37,751 THB¹ which is significantly higher than country's average of 26,081 THB (National Statistical Office, 2019). Given this, Bangkok represents the largest RHA market in the country as residents have more income and RHA services are widely available. A detailed breakdown of sociodemographic attributes of Bangkok residents in 2019 is shown in Fig. 1 (National Statistical Office, 2020).

The backbone of the public transportation system in Bangkok is its urban rail system, encompassing an elevated train, subway, and traditional rail lines. However, it does not cover all areas, especially those with low population density as illustrated in Fig. 1. The urban rail system is mostly used by middle-income residents as its pricing structure may not be accessible for low-income residents. We thus see that other main public transport systems — public buses and vans that operate 396 routes — are more affordable for low-income people. Beyond this, the available conventional for-hire public transport services include taxis and motorcycle taxis² with fleets of 83,593 and 85,850 vehicles, respectively.

Despite the growing public transportation infrastructure, several chronic problems persist. For one, there is insufficient capacity of public transport services to meet existing travel demand (Conc Thammasat Business School, 2019). In addition, existing public transport services face quality issues. Different systems are not integrated with each other; switching between different modes of transport — which are often operated by private companies as in the case of the skytrain and subway — requires purchasing separate tickets. Travelers have to make several transfers and the current system does not cover all areas of the city. Additionally, there are limited park and ride facilities at transit stations (Chalermpong and Ratanawaraha, 2019). For example, out of the 141 urban rail stations in operation, only 33 stations have park and ride facilities, and only two have designated parking spots for motorcycles (Office of Transport and Traffic Policy and Planning, 2017). Although these park and ride facilities are closely patrolled by security guards and are generally free from vandalism, their limited availability makes it difficult for potential passengers to access public transit, which in turn gives motorcycle taxis and RHA operators the opportunity to fill this gap (Chalermpong et al., 2018). Moreover, taxi drivers also regularly reject passengers based on their destination and may attempt to offer non-standard fares instead of using the taxi fare meter. Given these issues, it is not surprising that existing public transport problems have created the opportunity for on-demand ride-hailing services to grow in Bangkok.

The market value of RHAs in Thailand was 21,000 million THB (630 million USD) as of 2018 and is expected to reach 120,000 million THB (3,610 million USD) in 2025 (Conc Thammasat Business School, 2019). At the time of our study in November 2020, there were six ride-hailing applications available in Bangkok, as shown in Table 1. Three of them provide delivery services — food and small parcels — in addition to ride-hailing services. As of May 2020, Grab, the largest RHA operator in Bangkok, had more than 100,000 drivers. Thirty-five percent of Grab's drivers operated cars, 64 % drove motorcycles, and the remainder operated non-motorized vehicles. Twenty-three percent of Grab's fleet provided ride-hailing services and 77 % provided delivery services. Unfortunately, the available statistics for Grab's fleet did not provide a breakdown of the types of vehicles used for ride-hailing services (Techsauce Team, 2020).

3.2. Data collection methodology

To determine the proportion of RHA users in Bangkok, we conducted a large scale public survey with a sample size of 1000 people who were representative of the population in Bangkok. The target population included individuals aged 18 to 69 who reside in Bangkok, and we used stratified and quota sampling methods.

One of our core hypotheses was that the use of RHAs differs according to the availability of public transportation and travel needs of an individual. We therefore grouped fifty districts of Bangkok into 10 area groups according to government-defined districts and the accessibility of urban rail, as illustrated in Fig. 1. Using this method, we devised six areas with urban rail stations: central Bangkok, south Bangkok, north Bangkok, east Bangkok, north Thonburi, and south Thonburi. In contrast, the remaining four area groups without urban rail stations included north/east inner Bangkok, northeast outer Bangkok, inner Thonburi, and outer Thonburi. We collected samples evenly from these ten area groups, meaning one hundred samples were sourced from each area group. To obtain a representative population from each area group, the sampling quotas were determined based on the population proportions of age and gender in each area group in 2019 (National Statistical Office, 2020).

Respondents for the questionnaire were intercepted by trained surveyors and asked to answer eleven questions that took less than two minutes to complete, excluding the amount of time spent recruiting participants. The questionnaire was short and mostly contained close-ended questions in order to minimize survey time and inconvenience for participants, as can be seen in the Appendix. Seven questions asked about personal characteristics: age, gender, vehicle ownership, residential district, general travel mode, average daily travel time (min/day), and perceived number of travel options. General travel mode refers to the most frequently used travel mode, and the average daily travel time encompasses the travel time for all trip purposes and travel modes. In respect to the perceived number of travel options, respondents were asked about their perception of available travel modes, specifically if they think that there are many, limited, or no travel options available to them. The other four questions focused on the use of car and motorcycle RHAs: RHA adoption, RHA use frequency, RHA trip purpose, and RHA trip type (i.e., traveling point-to-point, connecting to other public transport). The survey was approved by the Research Ethics Review Committee of Chulalongkorn University (RERC). Since the questionnaire did not contain any personal information that can be used to identify the participant, the RERC did not require a written consent form to be signed by participants. The application for exemption of the written consent form for this survey was also reviewed and approved by the RERC.

The survey was conducted in Bangkok during November 2020, when the domestic confirmed COVID-19 cases in Bangkok were averaging 28 cases per day and there were no domestic travel restrictions in place (Department of Disease Control, 2021). In other words, people were allowed to travel as normal. However, travel demand had not returned to pre-pandemic period levels, as evident in the reduction in public transport ridership. The number of urban rail passengers during November 2020 was 25 % lower than the average number of urban rail monthly passengers in 2019 (Ministry of Transport Data Catalog, 2022). Respondents were recruited by intercept at public transport stations (i.e., bus stops, urban rail stations), markets (i.e., fresh-food markets, supermarkets), department stores, and parks. At the end of the survey, the total of 1177 samples were collected.

It should be noted that our surveyors faced various challenges in recruiting participants. For example, due to the COVID pandemic some people were reluctant to participate in a face-to-face survey. Accordingly, it was crucial that surveyors took precautions such as wearing masks, providing sanitizing gel to participants, and assuring participants that the survey would take as little amount of time as possible. In addition, some people avoided taking public transport in order to

¹ THB = Thai Baht (1 THB = 0.031 USD, as of July 14, 2021).

² Motorcycle taxis in Thailand are publicly regulated to operate in specific areas. In contrast, motorcycle RHA are privately operated and drivers can pick up riders in nearly any location. It is also worth noting that some conventional motorcycle taxi drivers also work for motorcycle RHA companies.

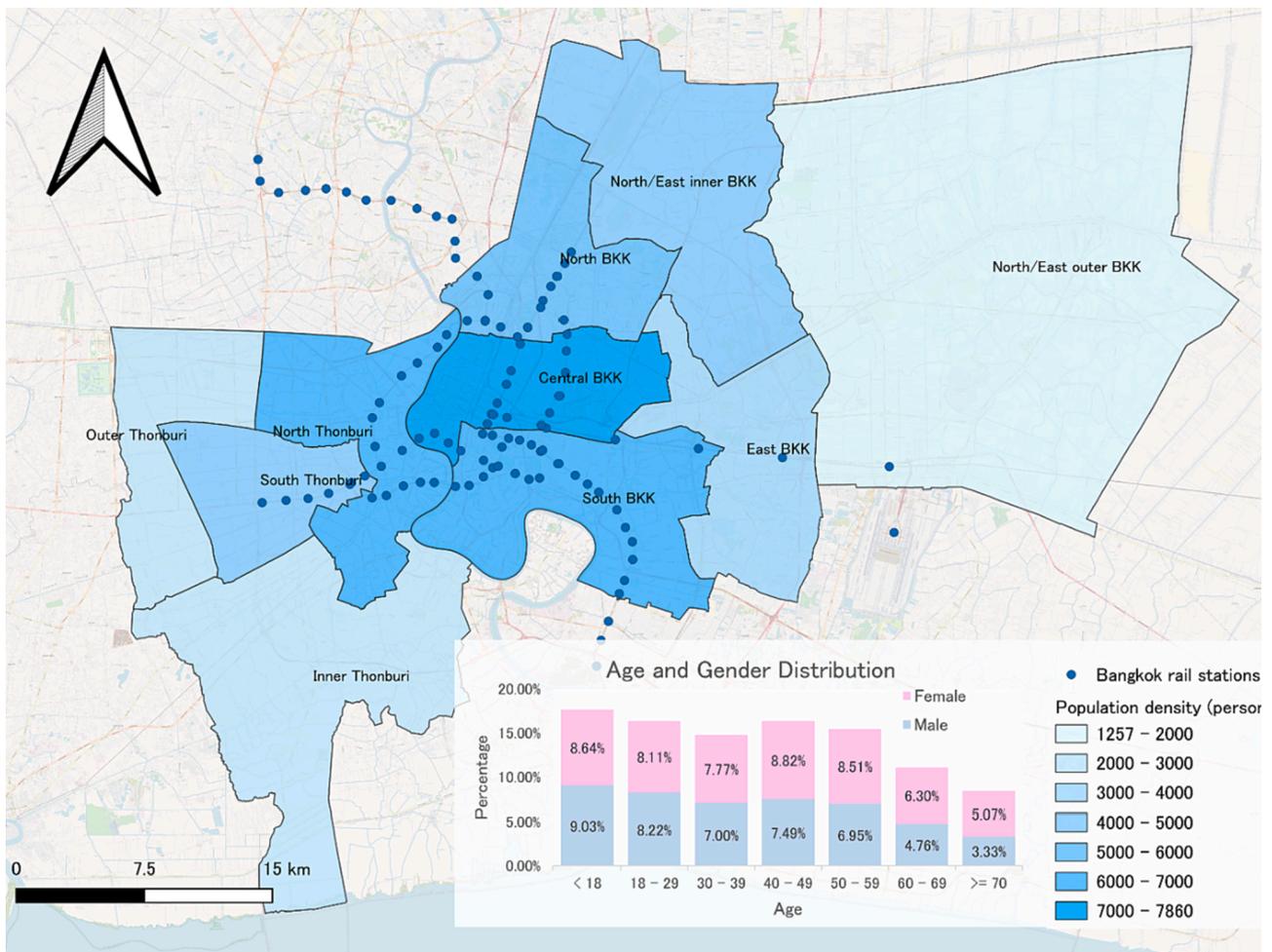


Fig. 1. Sociodemographics of Bangkok. (color figure).

Table 1
Ride-hailing applications in Bangkok.

Application	Services			
	Car RHA	Motorcycle RHA	Other RHA	Delivery
Grab	Driver's personal car Taxi	Driver's personal motorcycle Motorcycle taxi ³	Driver's personal van	Food Groceries Parcels/ Messenger
LINEMAN	Taxi	-	-	Food Groceries Parcels/ Messenger
Gojek	-	Motorcycle taxi	-	Food Parcels/ Messenger
Bolt	Driver's personal car Taxi	Motorcycle taxi	Driver's personal van	-
Taxi OK	Taxi	-	-	-
Muvmi	-	-	Tuk-tuk (3-wheeler)	-

³Motorcycle taxi refers to government regulated public motorcycle taxis. RHA motorcycle companies, such as Grab, allow drivers of public motorcycle taxis to also work for them.

minimize the risk of contracting COVID, particularly those among the high-income population who tended to own private vehicles. Since this population group is likely to reside in homes in gated communities or high-end condominiums with tight security, it was difficult for our surveyors to reach them at public transport hubs or gain access to conduct the survey near their homes. However, by conducting surveys at popular destinations frequently visited by people in the high-income group, such as high-end department stores or office buildings in central business districts, we were able to obtain a sample that better represents this population than if we only focused on public transport hubs or residential areas. However, it was necessary to formally request permission to conduct surveys at these locations, a step that took a substantial amount of time to complete.

3.3. Modeling methodology

The bivariate probit (BP) model (Greene, 2003), an extension of the univariate probit model, was employed for simultaneously examining the determinants of our two dependent variables and controlling for common unobserved factors affecting both dependent variables (e.g., attitudes about new technologies, smartphone skills). In the case of large sample size, the probit model generally provides a better statistical fit than the logit model (Hahn and Soyer 2005). Since our sample size was over 1,000, we chose the probit model for further analysis in this study. As a result, we can understand the interrelationship between two outcomes. This model has been used in several travel behavior studies (Fountas et al., 2019; Guo et al., 2017; Le-Klähn et al., 2015; Masiero and Zoltan, 2013), including RHA studies (Dias et al., 2017).

In this paper, we employed the bivariate binary and ordered probit models to explain the determinants of and the interrelationship between car and motorcycle RHA adoption as expressed in equation (1) and their use frequency as expressed in equation (2), respectively.

$$Y_{i,c}^b = \beta_c^b X_{i,c} + \varepsilon_{i,c}^b, \quad y_{i,c}^b = 1 \text{ if } Y_{i,c}^b > 0, \text{ and } y_{i,c}^b = 0 \text{ otherwise,}$$

$$Y_{i,m}^b = \beta_m^b X_{i,m} + \varepsilon_{i,m}^b, \quad y_{i,m}^b = 1 \text{ if } Y_{i,m}^b > 0, \text{ and } y_{i,m}^b = 0 \text{ otherwise,}$$
(1)

$$Y_{i,c}^o = \beta_c^o X_{i,c} + \varepsilon_{i,c}^o, \quad y_{i,c}^o = j \text{ if } \mu_{c,j} < Y_{i,c}^o \leq \mu_{c,j+1},$$

$$Y_{i,m}^o = \beta_m^o X_{i,m} + \varepsilon_{i,m}^o, \quad y_{i,m}^o = j \text{ if } \mu_{m,j} < Y_{i,m}^o \leq \mu_{m,j+1},$$
(2)

with the cross-equation correlated error terms for both models being defined as

$$\begin{pmatrix} \varepsilon_{i,c} \\ \varepsilon_{i,m} \end{pmatrix} \sim N \left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \rho \\ \rho & 1 \end{pmatrix} \right],$$
(3)

where Y denotes a latent dependent variable, X denotes a vector of determinants, β denotes a vector of coefficients associated with determinants, ε denotes a standard normally distributed random error term of the latent equation, y denotes a binary outcome, ρ denotes cross-equation correlation coefficient of ε , superscript b and o denote variables for binary and ordered models, respectively, subscript i denotes an individual, and subscript c and m denote the association of car and motorcycle RHA adoption, respectively. β and ρ can be estimated by simulated maximum likelihood estimation (Greene, 2003). ‘mvProbit’ and ‘mvdord’ packages in R were used for analyzing bivariate binary and ordered probit models, respectively.

4. Result

4.1. Descriptive statistics

Our samples were well-distributed as there were more than 100 samples from each area group and samples represented all age groups. Note that the number of female samples was slightly higher than the number of male samples, following the actual distribution shown in Fig. 1. Age and average daily travel time were collected and modelled as continuous variables, where their means and standard deviations are shown in parentheses next to variable names. For a more detailed breakdown, Table 2 provides descriptive statistics of sociodemographic and economic characteristics of all samples.

Table 3 shows the descriptive statistics comparing non-RHA users to RHA users. Notably, RHA users accounted for 42.40 % of the population in Bangkok and non-RHA users made up 57.60 % of the population. The proportion of female RHA users was slightly higher than female non-RHA users. The average age of RHA users was 35.53 years, which was substantially younger than the average age of non-RHA users at 43.14 years. In addition, a higher percentage of RHA users regularly used urban rail or taxis compared to non-RHA users. It should be noted that in this study, private motorcycle refers to all types of private two-wheeled motor vehicles. For motorcycle taxis, the engine capacity is limited to 125 cc according to government regulations. However, as of December 2022, there was no regulation on what types of motorcycles can be used to provide RHA services.

All types of motorcycles are not allowed on expressways. Two-up riding (i.e. one driver and one passenger) on any type of motorcycle is legally allowed. All motorcycle drivers are required by law to hold a personal motorcycle driving license and motorcycle taxi drivers are also required to hold a public motorcycle driving license.

As illustrated in Fig. 2, RHA users were individuals residing in areas with high population density, especially in central and south Bangkok where the proportion of RHA users is above 60 %. Among RHA users, car RHAs are more popular than motorcycle RHAs in all areas. However, proportions of RHA users who identified private vehicles — cars and

Table 2
Descriptive statistics of samples.

Variables	n	%	Variables	n	%
Total (N)	1177	100	<i>Travel options</i>		
<i>Gender</i>			Many	1003	80.72
Female	684	55.95	Limited	155	17.22
Male	493	44.05	None	19	2.06
<i>Age (mean = 39.92, std = 13.84)</i>			<i>Average daily travel time (mean = 58.61, std = 47.41)</i>		
18–29	329	27.37	<= 15 min	104	9.84
30–39	269	20.41	16–30 min	318	32.13
40–49	243	19.56	31–45 min	228	19.37
50–59	204	19.01	46–60 min	271	23.5
60–69	132	13.65	61–90 min	55	3.46
<i>Household vehicle ownership</i>			91–120 min	127	7.64
Car and MC ⁴	465	41.34	>120 min	74	4.06
Car only	154	12.68	<i>Area group</i>		
MC only	119	10.15	Central	125	10.62
Neither	439	35.82	Bangkok		
<i>Regular travel mode</i>			South	102	8.67
Private Car	202	20.03	Bangkok		
Private MC	77	6.04	North	115	9.77
Urban Rail	85	6.15	Bangkok		
Public Transport ⁵	757	62.93	East Bangkok	117	9.94
Taxi	31	2.68	North	148	12.57
MC Taxi	17	1.48	Thonburi		
Others	8	0.68	South	118	10.03
			Thonburi		
			North/East	103	8.75
			Inner		
			Bangkok		
			North/East	108	9.18
			Outer		
			Bangkok		
			Inner	115	9.77
			Thonburi		
			Outer	126	10.71
			Thonburi		

⁴MC stands for motorcycle.

⁵Public transport includes local buses, public vans, informal transport (e.g., Songtaew, Silor Lek).

motorcycles — as their regular travel mode were smaller than those of non-RHA users. This aligns with survey findings that a higher proportion of RHA users perceived that they have many travel options compared to non-RHA users. The average daily travel time of RHA users was found to be shorter than non-RHA users.

Table 4 shows different users’ characteristics grouped by modes of RHA. The modes of RHA were divided into three use groups: ‘only car RHA’, ‘only motorcycle RHA’, and ‘both car and motorcycle RHA’. Car RHA use is more common in Bangkok than motorcycle RHAs. Among 499 samples that were RHA users, 85.57 % of them had used car RHAs, while 49.30 % of them had used motorcycle RHAs.

The characteristics of users within ‘only car RHA’ and ‘both car and motorcycle RHA’ groups of RHA modes were quite similar to RHA users overall, but individuals who adopted ‘only motorcycle RHA’ displayed some unique characteristics. For one, these users were predominately male and older individuals when compared to other modes. This is different from the findings of motorcycle RHA user characteristics in Indonesia in which more than 70 % of motorcycle RHA users were female (Silalahi et al., 2017; Suatmadi et al., 2019). We also found that many ‘only motorcycle RHA’ users regularly travelled by private car, had a lower average daily travel time, and had lower rates of private motorcycle ownership compared to other groups. It is notable that individuals in the ‘only motorcycle RHA’ category reported the highest percentage of limited travel options among all RHA mode groupings.

There were 424 car RHA users and 242 motorcycle RHA users who answered questions related to use behaviors, including frequency of RHA use, general purpose of use, and trip type. As shown in Table 5, even though motorcycle RHAs were less likely to be adopted, they were

Table 3
Percentage of ride-hailing users.

Variables	Non-RHA		RHA	
	n	%	n	%
Total (N = 1177)	678	57.6	499	42.4
<i>Gender</i>				
Female	386	56.93	298	59.72
Male	292	43.07	201	40.28
<i>Age (mean, std)</i>				
	(43.14, 14.51)		(35.52, 11.53)	
18–29	159	23.45	170	34.07
30–39	104	15.34	165	33.07
40–49	151	22.27	92	18.44
50–59	153	22.57	51	10.22
60–69	111	16.37	21	4.21
<i>Household vehicle ownership</i>				
Car and MC	296	43.66	169	33.87
Car only	74	10.91	80	16.03
MC only	65	9.59	54	10.82
Neither	243	35.84	196	39.28
<i>Regular travel mode (Mode)</i>				
Private Car	138	20.35	64	12.83
Private MC	53	7.82	24	4.81
Urban Rail	25	3.69	60	12.02
Public Transport	443	65.34	314	62.93
Taxi	6	0.88	25	5.01
MC-Taxi	8	1.18	9	1.8
Others	5	0.74	3	0.6
<i>Travel options</i>				
Many	543	80.09	460	92.18
Limited	117	17.26	38	7.62
None	18	2.65	1	0.2
<i>Average daily travel time</i>				
	(62.45, 52.82)		(53.40, 38.33)	
<= 15 min	57	8.41	47	9.42
16–30 min	199	29.35	119	23.85
31–45 min	101	14.9	127	25.45
46–60 min	157	23.16	114	22.85
61–90 min	26	3.83	29	5.81
91–120 min	86	12.68	41	8.22
> 120 min	52	7.67	22	4.41
<i>Area group</i>				
Central Bangkok	46	6.78	79	15.83
South Bangkok	35	5.16	67	13.43
North Bangkok	64	9.44	51	10.22
East Bangkok	53	7.82	64	12.83
North Thonburi	94	13.86	54	10.82
South Thonburi	74	10.91	44	8.82
North/East Inner Bangkok	66	9.73	37	7.41
North/East Outer Bangkok	75	11.06	33	6.61
Inner Thonburi	82	12.09	33	6.61
Outer Thonburi	89	13.13	37	7.41

likely to be used more frequently than car RHAs as we hypothesized. Car RHA was likely to be used evenly for shopping, work, and social trips with similar proportions around 20 %. In contrast, motorcycle RHA was likely to be used for shopping trips, accounting for 45.05 % of all motorcycle trips. However, there are substantial proportions of motorcycle RHA users who reported using them for travel to and from work (23.55 %) and education (10.33 %). There is therefore some evidence that suggests motorcycle RHA is used for commuting, aligning with our hypothesis.

In terms of trip type, both car and motorcycle RHA are mostly used for traveling point-to-point. However, motorcycle RHA is used significantly more — at a rate nearly ten times higher — to connect to public transport (20.25 %) compared to car RHA (2.12 %), supporting our hypothesis that motorcycle RHA partially functions as a public transit feeder.

4.2. Who uses car and motorcycle RHAs?

Table 6 shows the results of our bivariate binary choice probit model. The two dependent variables are car and motorcycle RHA adoptions. The correlation parameter (ρ) was found to be positive and significant,

indicating that car RHA users are likely to use motorcycle RHA, and vice versa. Car and motorcycle RHA adoptions have some common significant determinants. Specifically, both car and motorcycle RHA users were young, regularly travelled by urban rail or taxi, and did not regularly use a private motorcycle, supporting our hypotheses of H1, H2, H3, H4, H8, H9, and H12.

However, differences between car and motorcycle RHA users also emerged. The results for car RHA users aligned with findings from previous studies (Tirachini, 2019) and supported our H3 in which car RHA users were found to be individuals who normally travelled by taxi, a direct competitor of car RHA. On the other hand, the results for motorcycle RHA users revealed that they were not conventional motorcycle taxi users as we had hypothesized (H11). This finding is contrary to the results from Indonesia (Irawan et al., 2020b) since it suggests that motorcycle RHA and conventional motorcycle taxis have different groups of users.

The specific characteristics of users that affected adoption of car RHA were perceived travel options and population density of one’s residential area. In particular, individuals who perceived that they have many travel options and reside in areas with a high population density were likely to adopt car RHA, which supported our hypotheses (H6 and H7).

For motorcycle RHA adoption, car ownership and access to urban rail stations played a role in user adoption. We found that individuals who owned private cars and resided in areas with a high density of urban rail stations were likely to adopt motorcycle RHA.

4.3. How are car and motorcycle RHAs used?

The use frequency of car and motorcycle RHA was analyzed using bivariate ordered probit regression, displayed in Table 7. Similar to the adoption of RHAs in the previous section, use frequency of car RHA significantly and positively correlated with use frequency of motorcycle RHA. In other words, individuals who frequently used car RHA were likely to frequently use motorcycle RHA, and vice versa.

The common significant determinants for use frequency of car and motorcycle RHA included age and general travel mode. Younger individuals were likely to use both car and motorcycle RHAs more frequently than older individuals. Additionally, individuals who regularly used urban rail and taxis were likely to use RHA more frequently than individuals who used other modes for regular transportation.

Importantly, motorcycle RHA use frequency was linked to several key user characteristics. Individuals who owned a private car, reported short average daily travel times, or resided in areas with high urban rail station density were likely to frequently use motorcycle RHA. In contrast, individuals who owned private motorcycles and regularly used them to travel were less likely to frequently use motorcycle RHA. Car RHA use frequency only had one key significant determinant: perceived travel options.

5. Discussion

According to our survey results, the share of RHA users was 42.40 % of the population in Bangkok. Among all RHA users, car RHA was adopted more than motorcycle RHA. Specifically, 85.57 % of RHA users adopted car RHA, while 49.30 % of RHA users adopted motorcycle RHA. Our results show that characteristics of car and motorcycle RHA users had common overlaps but were also different in key ways.

The common characteristics of all RHA users are that they are largely younger individuals who use urban rail and taxis. This suggests that RHA is partially being used as a substitution for a competing transport mode, conventional taxis. It also reveals a significant association between urban rail and RHA users. Car RHA users were found to be individuals who perceived that they have many travel options, suggesting that car RHA is selected by these individuals over other transportation modes if it can better satisfy travelers’ needs. Similarly, most motorcycle RHA users resided in areas with many urban rail stations and they were often

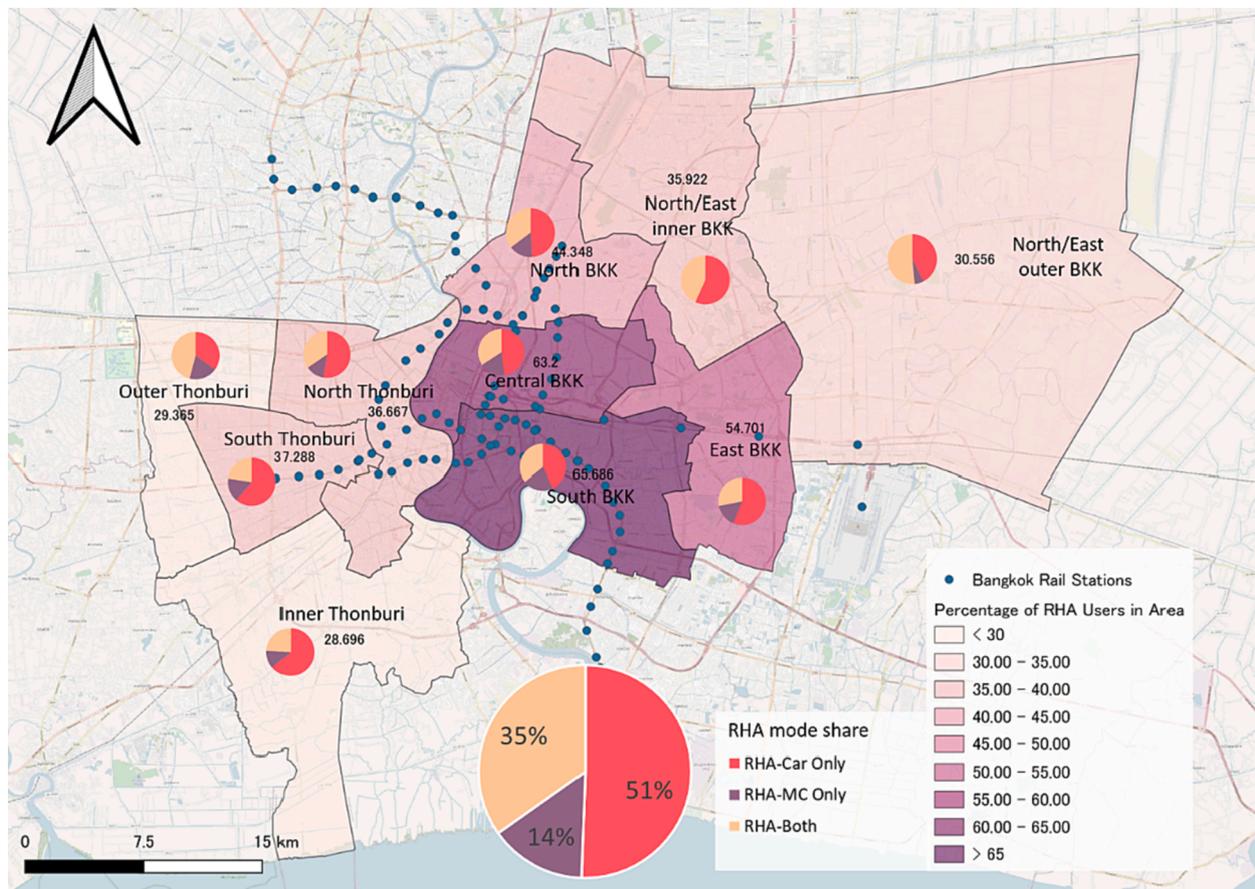


Fig. 2. Proportion of RHA users by area (color figure).

individuals who owned a private car. This finding shows that motorcycle RHA could serve to substitute private car trips as it has the potential to save time by providing fast access to public transport.

RHA use behaviors, frequency of use, and purpose depend significantly on the mode of RHA. Even though car RHAs were more popular than motorcycle RHAs in terms of overall adoption, motorcycle RHAs were likely to be used more frequently than car RHAs. This may be because motorcycle RHA is used for commuting trips (i.e., work and education trips) more than car RHA. Furthermore, motorcycle RHA was used as means of connecting to public transportation significantly more than car RHA — aligning with one of our key hypotheses that motorcycle RHA can act as a feeder to public transit.

Our results reveal that motorcycle RHA trips can both substitute and complement public transport, especially the urban rail system, as we found a positive association between motorcycle RHA users and urban rail station density. It is unclear why and under what conditions passengers decide to use motorcycle RHA to substitute public transit, but it may be tied to cost as short-distance motorcycle RHA trips may be cheaper than urban rail. Likewise, we do not have conclusive data on the factors driving motorcycle RHA to act as a feeder to urban rail, but it is possible that it is filling a need for better access to public transit, especially for underserved populations. We recommend that future research explores why and how passengers decide to use motorcycle RHA to substitute or complement public transportation.

In addition, while our results show that car RHA acts as a substitute for its direct competing travel mode, (i.e., conventional taxis), this does not hold true for motorcycle RHA as users are not using them to replace conventional motorcycle taxis. It is possible that passengers of conventional motorcycle taxis have not faced as many problems as passengers of conventional taxis, thereby reducing the tendency to use RHA as a means of substitution. Further, given the operational zoning of

conventional motorcycle taxi stands in Bangkok, motorcycle RHA drivers may not be able to operate in these areas.

6. Policy recommendations

There are two key takeaways from our research that have implications for transportation and urban planning policy, particularly on how RHA may affect the number of private vehicles on the road and how motorcycle RHA acts as a feeder to public transit. At the same time, policymakers should consider how RHA impacts traffic congestion and ensure safety protections and accessibility for all users.

First, the proportions of RHA users who identified private vehicles — cars and motorcycles — as their regular travel mode were smaller than those of non-RHA users. Moreover, we found that frequent motorcycle RHA users were individuals who did not own private motorcycles. This may suggest that adoption of RHA decreases the use of a private vehicle.

Second, our results revealed that motorcycle RHA is partially being used to connect to public transportation in Bangkok and that this feeder function is occurring at a rate nearly ten times higher than that of car RHA. Based on this finding, we propose exploring how RHA can be used to increase access public transit, especially for underserved populations.

There is an understandably complex relationship between RHA and public transportation in Bangkok, but there may be ways to synergize them, including offering incentives or fare discounts for RHA users who use these platforms in order to connect to public transit. Since the RHA business is, in general, profit-oriented, public subsidies may be required. For example, this could potentially be done by individual transit agencies or through a collaboration between transit agencies and RHA operators. Similarly, in addition to RHA fare pricing comparisons, users could also see an estimated carbon footprint from their trips, thereby showing that connecting to public transit will produce less emissions

Table 4
RHA users' characteristics grouped by modes of RHA.

Variables	Only car RHA		Only MC RHA		Both car and MC RHA	
	n	%	n	%	n	%
Total (N = 499)	253	50.70	72	14.43	174	34.87
Gender						
Female	153	60.47	34	47.22	111	63.79
Male	100	39.53	38	52.78	63	36.21
	(35.92, 11.04)		(37.61, 11.07)		(34.07, 12.01)	
Age (mean, std)						
18–29	75	29.64	16	22.22	79	45.4
30–39	96	37.94	26	36.11	43	24.71
40–49	46	18.18	17	23.61	29	16.67
50–59	24	9.49	11	15.28	16	9.20
60–69	12	4.74	2	2.78	7	4.02
Household vehicle ownership						
Car and MC	79	31.23	24	33.33	66	37.93
Car only	35	13.83	16	22.22	29	16.67
MC only	32	12.65	4	5.56	18	10.34
Neither	107	42.29	28	38.89	61	35.06
Regular travel mode						
Private Car	32	12.65	15	20.83	17	9.77
Private MC	16	6.32	3	4.17	5	2.87
Urban Rail	30	11.86	6	8.33	24	13.79
Public Transport	161	63.64	45	62.5	108	62.07
Taxi	8	3.16	2	2.78	15	8.62
MC-Taxi	5	1.98	1	1.39	3	1.72
Others	1	0.40	0	0.00	2	1.15
Travel options						
Many	242	95.65	60	83.33	158	90.8
Limited	11	4.35	12	16.67	15	8.62
No	0	0.00	0	0.00	1	0.57
Average daily travel time	(53.82, 38.47)		(43.65, 25.98)		(56.82, 41.77)	
<= 15 min	21	8.30	8	11.11	18	10.34
16–30 min	62	24.51	24	33.33	33	18.97
31–45 min	66	26.09	15	20.83	46	26.44
46–60 min	57	22.53	17	23.61	40	22.99
61–90 min	13	5.14	5	6.94	11	6.32
91–120 min	24	9.49	2	2.78	15	8.62
greater than 120 min	10	3.95	1	1.39	11	6.32
Area group						
Central Bangkok	38	15.02	14	19.44	27	15.52
South Bangkok	29	11.46	14	19.44	24	13.79
North Bangkok	25	9.88	8	11.11	18	10.34
East Bangkok	36	14.23	10	13.89	18	10.34
North Thonburi	29	11.46	6	8.33	19	10.92
South Thonburi	27	10.67	7	9.72	10	5.75
North/East Inner Bangkok	21	8.30	0	0.00	16	9.20
North/East Outer Bangkok	14	5.53	2	2.78	17	9.77
Inner Thonburi	21	8.30	4	5.56	8	4.60
Outer Thonburi	13	5.14	7	9.72	17	9.77

compared to a point-to-point RHA trip.

Still, we have qualifications to how RHA can be integrated with public transport planning, separating out the different characteristics of motorcycle and car RHA use. Chiefly, motorcycle RHA should be optimized in urban areas to synchronize connections to the urban rail system

Table 5
Descriptive statistics of car and motorcycle ride-hailing use behaviors.

RHA usage	Car		MC	
	n	%	n	%
Total	424	100	242	100
Frequency				
<1 time/month	131	30.90	59	24.38
1 time/month or less	82	19.34	37	15.29
2–3 times/month	142	33.49	87	35.95
1 time/week	35	8.25	20	8.26
2–3 times/week	21	4.95	29	11.98
3 times/week or more	13	3.07	10	4.13
General Purpose				
Social	79	18.63	16	6.61
Work	101	23.82	57	23.55
Shopping	91	21.46	109	45.04
Education	27	6.37	25	10.33
Restaurant/Coffee shop	8	1.89	2	0.83
Health-related trip	13	3.07	2	0.83
Airport	14	3.30	0	0.00
Traveling in other cities	59	13.92	22	9.09
Others	32	7.55	9	3.72
Trip type				
Point-to-Point	414	97.64	193	79.75
To/From public transport hub (Feeder)	9	2.12	49	20.25
NA	1	0.24	0	0.00

as there is some evidence from our study that motorcycle RHA has the potential to complement the urban rail system. In practice, this could be supported by offering bundle pricing packages that promote motorcycle RHA as a feeder to public transit and implemented through the development of Mobility as a Service (MaaS) application with the integrated fare scheme. Best practices and lessons learned can be taken from MaaS pilot projects (e.g., Ubigo in Stockholm, Sweden; the smile project in Vienna, Austria) when considering implementation in Bangkok (Jit-trapirom et al., 2020). To support such offerings, the government transport planning authority should aim to support measures for motorcycle RHA to serve populations underserved by public transit and incentivize connector trips to public transit. In contrast, we suggest that car RHA services should be focused in suburban areas as there is the potential for car RHA to compete with the existing urban public transport system due to its point-to-point trip nature.

More broadly, there are important challenges to be addressed in transportation and urban planning policy on RHA, particularly around traffic congestion, safety, and accessibility. For one, we found that RHA users primarily lived in urban areas in which traffic congestion is a serious problem, meaning users may be picked up or dropped off in the middle of traffic, risking their safety and causing traffic congestion. Accordingly, there is a need to designate pick-up and drop-off areas for RHA in dense urban areas in order to mitigate traffic congestion that may occur. Such designation has been implemented for car RHA in multiple cities (e.g., San Francisco, United States of America; Sydney, Australia; Amsterdam, the Netherlands), especially at airports. Location-based RHA platforms could implement geofencing and enforce designated pick-up and drop-off areas to address this issue.

Secondly, safety regulations should be consistent across both motorcycle RHA and public motorcycle taxis. Regulations on driver training, safe driving speed, holding a valid driver's license, and operating with high-quality helmets for passengers should cover both forms of motorcycle transportation in order to ensure passenger safety. Drivers may drive over the speed limit in order to complete trips faster and gain more passengers and income (Nguyen-Phuoc et al., 2020a). Regulations should disincentivize this dangerous behavior by enforcing safety rules and ensuring drivers who adhere to them do not earn less simply because they complete fewer trips.

Finally, it is worth RHA companies considering how they can be more inclusive, especially for the elderly who are less familiar with RHA. Approximately 79.56 % of individuals aged 50 – 59 years old who live in

Table 6
Bivariate binary choice probit (BP) model for RHA adoption.

	Car			Motorcycle		
	Coef.	Std. Err	P-value	Coef.	Std. Err	P-value
Constant	-0.304	0.253	0.230	-0.169	0.261	0.518
Age	-0.027	0.003	0.000	-0.024	0.004	0.000
Gender (reference = Female)						
Male	-0.088	0.083	0.289	0.009	0.091	0.917
Car Ownership	0.151	0.103	0.142	0.387	0.107	0.000
MC Ownership	-0.020	0.097	0.841	-0.134	0.105	0.202
Average daily travel time	-0.002	0.001	0.129	-0.002	0.001	0.066
Regular Mode (reference = Public transport)						
Urban rail	0.555	0.148	0.000	0.301	0.151	0.046
Private Car	-0.189	0.123	0.124	-0.177	0.138	0.198
Private MC	-0.321	0.179	0.073	-0.523	0.219	0.017
Taxi	1.216	0.283	0.000	1.028	0.245	0.000
MC-Taxi	0.270	0.330	0.413	0.098	0.356	0.782
Others	0.047	0.680	0.945	0.340	0.755	0.653
Travel Option (reference = limited or no options)						
Many options	0.737	0.135	0.000	0.155	0.137	0.257
Characteristics of zone of residence						
Population density	0.742	0.402	0.065	-0.297	0.474	0.530
Urban rail density	0.026	0.981	0.979	2.600	1.126	0.021
Correlation (ρ)	0.533	0.046	0.000			
Log-likelihood	-1168.329					
Number of Observations	1177					
Degree of Freedom	1146					
AIC	2398.658					

Table 7
Bivariate ordered probit model for RHA use frequency.

	Car			Motorcycle		
	Coef.	Std. Err	P-value	Coef.	Std. Err	P-value
Constant	-0.421	0.241	0.080	-0.213	0.270	0.431
Age	-0.024	0.003	0.000	-0.024	0.004	0.000
Gender (reference = Female)						
Male	-0.072	0.077	0.353	0.045	0.087	0.610
Car Ownership	0.138	0.095	0.149	0.389	0.105	0.000
MC Ownership	0.006	0.092	0.949	-0.213	0.102	0.038
Average daily travel time	-0.001	0.001	0.448	-0.002	0.001	0.048
Regular Mode (reference = Public transport)						
Urban rail	0.558	0.131	0.000	0.278	0.155	0.073
Private Car	-0.158	0.114	0.166	-0.093	0.138	0.498
Private MC	-0.272	0.169	0.107	-0.430	0.212	0.042
Taxi	1.074	0.218	0.000	0.957	0.219	0.000
MC-Taxi	0.360	0.249	0.147	0.295	0.302	0.329
Others	-0.163	0.567	0.774	1.017	0.382	0.008
Travel Option (reference = limited or no options)						
Many options	0.694	0.132	0.000	0.235	0.143	0.101
Characteristics of zone of residence						
Population density	0.576	0.370	0.119	-0.384	0.475	0.419
Urban rail density	0.392	0.898	0.662	2.577	1.139	0.024
Threshold						
1 2	0.360	0.031	0.000	0.204	0.027	0.000
2 3	0.628	0.041	0.000	0.355	0.037	0.000
3 4	1.351	0.066	0.000	0.887	0.064	0.000
4 5	1.727	0.091	0.000	1.106	0.082	0.000
5 6	2.177	0.121	0.000	1.777	0.181	0.000
Correlation (ρ)	0.565	0.034	0.000			
Log-likelihood	-2149.441					
Number of Observations	1177					
Degree of Freedom	1134					
AIC	4384.882					

urban areas in Thailand have access to the internet, yet only 10.22 % of them have experienced using RHA (National Statistical Office, 2021).

7. Conclusion

This study investigated the differences and similarities between car and motorcycle ride-hailing applications (RHA) in terms of the factors affecting their adoption and use. The bivariate probit models and

descriptive statistics were used for analyzing the determinants of RHA adoption using data from an intercept survey in Bangkok.

We formulated hypotheses on car and motorcycle RHA use and adoption in Bangkok. Our findings confirmed some of our initial hypotheses. Specifically, our findings support the synergy hypothesis between car and motorcycle RHA based on the highly significant correlation between the two modes in the bivariate probit models. The emergence of car RHA has also introduced issues of competition with

public transportation, and taxis, its direct competitor. While motorcycle RHA was partially used to complement existing public transport — serving as a connector — car RHA was used to substitute public transport. This suggests urban planning and transportation policy in Bangkok must consider how RHA use may be impacting public transportation ridership. RHAs should aim to enhance accessibility of public transportation for the general population, particularly those underserved by public transit, and not be in direct competition with it. Transportation and urban planning policies should thus aim to synergize RHA with public transit.

There are some limitations in this study. This study focused only on demand-side of RHA. However, RHA users characteristics and their travel behaviors may be affected by the interactions between RHA demand and supply, specifically how demand concentration affects supply and vice versa. Future research should also incorporate RHA operation (e.g., ride cost, insurance availability) and supply characteristics to better understand their relationships. Additionally, since the built environment (e.g., park and ride facilities) may affect travel demand, it is equally important to examine the relationship between demand of ride-hailing services and the built environment. Finally, it is worth investigating how RHA users make decisions on private vehicle ownership and using public transport services, particularly what factors (e.g., cost, time, convenience, supply, demand) influence such decisions as our study found significant associations.

CRedit authorship contribution statement

Phathinan Thaitatkul: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft. **Saksith Chalermpong:** Conceptualization, Methodology, Formal analysis, Writing – review & editing, Supervision. **Wattana Laosinwattana:** Investigation, Data curation. **Jamison Liang:** Writing – original draft, Writing – review & editing. **Hironori Kato:** Conceptualization, Supervision, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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References

- Alemi, F., Circella, G., Handy, S., Mokhtarian, P., 2018. What influences travelers to use Uber? Exploring the factors affecting the adoption of on-demand ride services in California. *Travel Behav. Soc.* <https://doi.org/10.1016/j.tbs.2018.06.002>.
- Alemi, F., Circella, G., Mokhtarian, P., Handy, S., 2019. What drives the use of ridehailing in California? Ordered probit models of the usage frequency of Uber and Lyft. *Transp. Res. Part C Emerg. Technol.* 102, 233–248. <https://doi.org/10.1016/j.trc.2018.12.016>.

- Brail, S., 2020. World cities of ride-hailing. *Urban Geogr.* 00, 1–22. <https://doi.org/10.1080/02723638.2020.1775030>.
- Clewell, R.R., Mishra, G.S., 2017. Disruptive Transportation: The Adoption, Utilization, and Impacts of Ride-Hailing in the United States. *Inst. Transp. Stud. Univ. California, Davis*. doi: 10.1139/gen-44-3-401.
- Conc Thammawat Business School, 2019. Ride-hailing service industry.
- Contreras, S.D., Paz, A., 2018. The effects of ride-hailing companies on the taxicab industry in Las Vegas, Nevada. *Transp. Res. Part A Policy Pract.* doi: 10.1016/j.tra.2017.11.008.
- Department of Disease Control, 2021. Covid-19 Situation Reports.
- Chalermpong, S., Kato, H., Thaitatkul, P., Ratanawaraha, A., Fillone, A., Hoang-Tung, N., Jittrapirom, P., 2022. Ride-hailing applications in Southeast Asia: A literature review. *International Journal of Sustainable Transportation*. <https://doi.org/10.1080/15568318.2022.2032885>.
- Chalermpong, S., Ratanawaraha, A., 2019. Chapter 12 Bangkok. In: Pojani, D., Corcoran, J., Sipe, N., Mateo-Babiano, I., Stead, D. (Eds.), *Parking: An International Perspective*. Elsevier, pp. 207–227.
- Chalermpong, S., Ratanawaraha, A., Maneenoy, N., Chullabodhi, C., 2018. User characteristics and effectiveness of a park and ride facility in Bangkok. *Engineering Journal* 22 (3), 1–10.
- Dias, F.F., Lavieri, P.S., Garikapati, V.M., Astroza, S., Pendyala, R.M., Bhat, C.R., 2017. A behavioral choice model of the use of car-sharing and ride-sourcing services. *Transportation (Amst)*. 44, 1307–1323. <https://doi.org/10.1007/s11116-017-9797-8>.
- Didi, 2021. Didiglobal [WWW Document]. URL <https://www.didiglobal.com/> (accessed 8.9.21).
- Fountas, G., Pantangi, S.S., Hulme, K.F., Anastasopoulos, P.C., 2019. The effects of driver fatigue, gender, and distracted driving on perceived and observed aggressive driving behavior: A correlated grouped random parameters bivariate probit approach. *Anal. Methods Accid. Res.* 22, 100091 <https://doi.org/10.1016/j.amar.2019.100091>.
- Grab, 2021. Transport services [WWW Document]. URL <https://www.grab.com/> (accessed 8.20.21).
- Greene, W.H., 2003. *Econometric Analysis, 5th Ed.* Pearson Education.
- Guo, Y., Zhou, J., Wu, Y., Chen, J., 2017. Evaluation of Factors Affecting E-Bike Involved Crash and E-Bike License Plate Use in China Using a Bivariate Probit Model. *J. Adv. Transp.* 2017 <https://doi.org/10.1155/2017/2142659>.
- Hahn, E.D., Soyer, R., 2005. Probit and logit models: Differences in the multivariate realm. *J. R. Statist. Soc., Series B* 67, 1–12.
- Irawan, M.Z., Belgiawan, P.F., Joewono, T.B., Simanjuntak, N.I.M., 2020a. Do motorcycle-based ride-hailing apps threaten bus ridership? A hybrid choice modeling approach with latent variables. *Public Transp.* 12, 207–231. <https://doi.org/10.1007/s12469-019-00217-w>.
- Irawan, M.Z., Belgiawan, P.F., Tarigan, A.K.M., Wijanarko, F., 2020b. To compete or not compete: exploring the relationships between motorcycle-based ride-sourcing, motorcycle taxis, and public transport in the Jakarta metropolitan area. *Transportation (Amst)*. 47, 2367–2389. <https://doi.org/10.1007/s11116-019-10019-5>.
- Irawan, M.Z., Rizki, M., Chalermpong, S., Kato, H., 2022. Mapping the motorcycle-based ride-hailing users in Yogyakarta: An analysis of socio-economic factors and preferences. *Asian Transport Studies* 8, 100073.
- Jittrapirom, P., Marchau, V., van der Heijden, R., Meurs, H., 2020. Future implementation of mobility as a service (MaaS): Results of an international Delphi study. *Travel Behav. Soc.* 21, 281–294. <https://doi.org/10.1016/j.tbs.2018.12.004>.
- Kong, H., Moody, J., Zhao, J., 2020. ICT's impacts on ride-hailing use and individual travel. *Transp. Res. Part A Policy Pract.* 141, 1–15. <https://doi.org/10.1016/j.tra.2020.08.012>.
- Laosinwattana, W., Thaitatkul, P., Chalermpong, S., 2023. In: Anjaneyulu, M.V.L.R., Harikrishna, M., Arkatkar, S.S., Veeraragavan, A. (Eds.), *Recent Advances in Transportation Systems Engineering and Management. Lecture Notes in Civil Engineering*, 261. Springer, Singapore. https://doi.org/10.1007/978-981-19-2273-2_53.
- Lavieri, P.S., Bhat, C.R., 2019. Investigating objective and subjective factors influencing the adoption, frequency, and characteristics of ride-hailing trips. *Transp. Res. Part C Emerg. Technol.* 105, 100–125. <https://doi.org/10.1016/j.trc.2019.05.037>.
- Le-Klähn, D.T., Roosen, J., Gerike, R., Hall, C.M., 2015. Factors affecting tourists' public transport use and areas visited at destinations. *Tour. Geogr.* 17, 738–757. <https://doi.org/10.1080/14616688.2015.1084527>.
- Masiero, L., Zoltan, J., 2013. Tourists intra-destination visits and transport mode: A bivariate probit model. *Ann. Tour. Res.* 43, 529–546. <https://doi.org/10.1016/j.annals.2013.05.014>.
- Ministry of Transport Data Catalog, 2022. Travel Demand Statistics [WWW Document]. URL <https://datagov.mot.go.th/dataset/covid-19/resource/71a552d0-0fea-4e05-b78c-42d58aa88db6> (accessed 1.26.22).
- National Statistical Office, 2019. Average Monthly Income per Household by Region and Province: 2002–2019.
- National Statistical Office, 2020. Number of Population from Registration by Region, Province, District and Area : 2018–2020.
- National Statistical Office, 2021. The 2021 (quarter 2) household survey on the use of information and communication technology.
- Nguyen-Phuoc, D.Q., De Gruyter, C., Nguyen, H.A., Nguyen, T., Ngoc Su, D., 2020a. Risky behaviours associated with traffic crashes among app-based motorcycle taxi drivers in Vietnam. *Transp. Res. Part F Traffic Psychol. Behav.* 70, 249–259. <https://doi.org/10.1016/j.trf.2020.03.010>.
- Nguyen-Phuoc, D.Q., Su, D.N., Tran, P.T.K., Le, D.T.T., Johnson, L.W., 2020b. Factors influencing customer's loyalty towards ride-hailing taxi services – A case study of

- Vietnam. *Transp. Res. Part A Policy Pract.* 134, 96–112. <https://doi.org/10.1016/j.tra.2020.02.008>.
- Nistal, P.D., Regidor, J.R.F., 2016. Comparative Study of Uber and Regular Taxi Service Characteristics. *Proc. 23rd Annu. Conf. Transp. Sci. Soc. Philipp.*
- Office of the national economic and social development council, 2019. *Gross Regional and Provincial Product Chain Volume Measures 2019 Edition*.
- Office of Transport and Traffic Policy and Planning, 2017. *Park and Ride System Implementation in Bangkok Metropolitan*. <https://www.otp.go.th/index.php/edureport/view?id=144&id=144> (accessed 11.1.2022).
- Paronda, A.G.A., Regido, J.R.F., Napalang, M.S.G., 2016. Comparative Analysis of Transportation Network Companies (TNCs) and Conventional Taxi Services in Metro Manila. In: *23rd Annu. Conf. Transp.*, pp. 1–12.
- Phun, V.K., Kato, H., Chalermpong, S., 2019. Paratransit as a connective mode for mass transit systems in Asian developing cities: Case of Bangkok in the era of ride-hailing services. *Transp. Policy* 75, 27–35. <https://doi.org/10.1016/j.tranpol.2019.01.002>.
- Ratanawaraha, A., Chalermpong, S., 2015. Monopoly rents in motorcycle taxi services in Bangkok. *Thailand Transportation Research Record* 2512, 66–72.
- Rizki, M., Basuki, T., Fajarindra, P., Zudhy, M., 2021. The travel behaviour of ride-sourcing users, and their perception of the usefulness of ride-sourcing based on the users' previous modes of transport: A case study in Bandung City, Indonesia. *IATSS Res.* <https://doi.org/10.1016/j.iatssr.2020.11.005>.
- Silalahi, S.L.B., Handayani, P.W., Munajat, Q., 2017. Service Quality Analysis for Online Transportation Services: Case Study of GO-JEK. *Procedia Comput. Sci.* 124, 487–495. <https://doi.org/10.1016/j.procs.2017.12.181>.
- Suatmadi, A.Y., Creutzig, F., Otto, I.M., 2019. On-demand motorcycle taxis improve mobility, not sustainability. *Case Stud. Transp. Policy* 7, 218–229. <https://doi.org/10.1016/j.cstp.2019.04.005>.
- Tang, B.J., Li, X.Y., Yu, B., Wei, Y.M., 2019. How app-based ride-hailing services influence travel behavior: An empirical study from China. *Int. J. Sustain. Transp.* 1–15. <https://doi.org/10.1080/15568318.2019.1584932>.
- Techsauc Team, 2020. *Grab discloses the statistics of young generation's alternative and flexible jobs* [WWW Document]. Techsauc. URL <https://techsauc.co/pr-news/gra-b-data-partner-part-time-work> (accessed 10.27.22).
- Teo, B.-C., Mustafa, M.A., Rozi, A.I.M., 2018. To Grab or Not to Grab?: Passenger Ride Intention towards E-Hailing Services. *Malaysian J. Consum. Fam. Econ.* 21, 153–163.
- Thaithatkul, P., Anuchitchanchai, O., Srisurin, P., Sanghatawatana, P., Chalermpong, S., 2021. Ride-Hailing Applications in Bangkok: Determining Service Quality, Passenger Satisfaction, and Loyalty. *Int. J. Technol.* 12.
- The Bureau of Registration Administration, 2021. *Thailand's registered population 2020*.
- Thaithatkul, P., Chalermpong, S., Laosinwattana, W., Liang, J., Kato, H., 2023. The Relationship between RHA Use and Car Purchases: Trends Emerging in Bangkok, Thailand. *Asian Transport Studies (ATS)* 9, 100095. <https://doi.org/10.1016/j.eastsj.2022.100095>.
- Tirachini, A., 2019. Ride-hailing, travel behaviour and sustainable mobility: an international review. In: *Transportation*. Springer, US. <https://doi.org/10.1007/s11116-019-10070-2>.
- Tirachini, A., del Río, M., 2019. Ride-hailing in Santiago de Chile: Users' characterisation and effects on travel behaviour. *Transp. Policy* 82, 46–57. <https://doi.org/10.1016/j.tranpol.2019.07.008>.
- Tuan, V.A., Mateo-babiano, I.B., 2013. Motorcycle Taxi Service in Vietnam – Its Socioeconomic Impacts and Policy Considerations. *J. East. Asia Soc. Transp. Stud.* 10.
- Uber, 2021. *Uber ride options* [WWW Document]. URL <https://www.uber.com/us/en/ride/ride-options/> (accessed 8.9.21).
- Wadud, Z., 2020. The effects of e-ridehailing on motorcycle ownership in an emerging-country megacity. *Transp. Res. Part A Policy Pract.* 137, 301–312. <https://doi.org/10.1016/j.tra.2020.05.002>.
- Weng, G.S., Zailani, S., Iranmanesh, M., Hyun, S.S., 2017. Mobile taxi booking application service's continuance usage intention by users. *Transp. Res. Part D Transp. Environ.* 57, 207–216. <https://doi.org/10.1016/j.trd.2017.07.023>.
- Wicaksono, A., Sulistio, H., Wahyudi, A., Bramiana, D.A., 2017. Evaluation of Online Motorcycle Taxi Performance in Surabaya and Sidoarjo Area, Indonesia. *J. Technol. Soc. Sci.* 1, 27–32.
- Young, M., Farber, S., 2019. The who, why, and when of Uber and other ride-hailing trips: An examination of a large sample household travel survey. *Transp. Res. Part A Policy Pract.* 119, 383–392. <https://doi.org/10.1016/j.tra.2018.11.018>.
- Irawan, M.Z., Joewono, T.B., Belgiawan, P.F., Chalermpong, S., Thaithatkul, P. (2022) Examining the ride-hailing adoption behaviors among older adults in an Indonesian city: The case of Yogyakarta. *Transportation Research Interdisciplinary Perspectives*, Vol.16, December 2022, 100729. doi:10.1016/j.trip.2022.100729.